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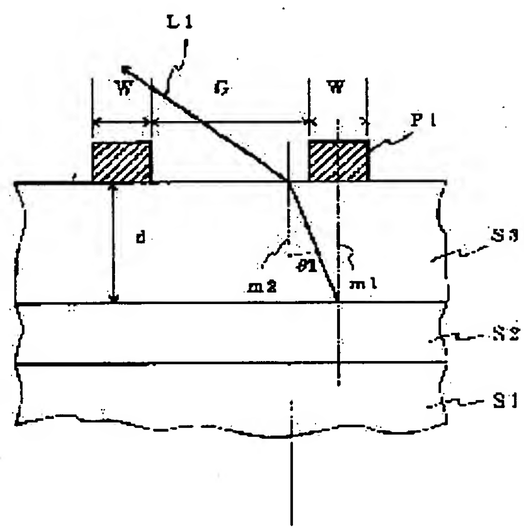
(54) GaN-BASED SEMICONDUCTOR LIGHT-EMITTING ELEMENT AND GaN- BASED SEMICONDUCTOR PHOTODETECTING ELEMENT

(57)Abstract:
PROBLEM TO BE SOLVED: To obtain a GaN-based light-emitting element excellent in light emitting characteristic by improving the structure of a light leading-out side electrode, and obtain a GaN-based photodetecting element excellent in light receiving characteristic by improving the structure of a light-fetching side electrode.
SOLUTION: The forming pattern of upper electrodes P1 has a repetition part, where covered regions in which the upper surface of a contact layer S3 is covered the electrode P1 and exposed regions in which the upper surface of the layer 3 is not covered but exposed, are alternately arranged. In the repetition part, a width of the covered region is W, a width of the exposed region is G, a depth from the upper surface of the contact layer S3 to a light-emitting layer S2 is (d), refractive index of the contact layer is n1, and refractive index of the outside is n2. In this case, W≤10 μm, W≤2G, and G≤dxtanθ1 (where θ1=sin-1(n2/n1)) are satisfied. Furthermore, other various kinds of modes are imparted to the upper electrode.



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CLAIMS

[Claim(s)]
[Claim 1] It is the GaN system semiconductor light emitting device which has a luminous layer which consists of a GaN system material, an up electrode is prepared through a contact layer which is from a GaN system material for forming an electrode on an upper part side of a luminous layer by making into an upper part side a side which light leaves to the external world to a luminous layer, and, for a formation pattern of this up electrode, this electrode is a wrap covering field about the contact layer upper surface. A repeat portion with which an exposed region which this electrode does not cover the contact layer upper surface, but is exposed was located in a line by turns Are the GaN system semiconductor light emitting device equipped with the above, and set width of face of each covering field about the direction of a repeat to W, and width of face of each exposed region is set to G. a time of setting [the depth from the contact layer upper surface to a luminous layer] a refractive index of n1 and the external world to n2 for a refractive index of d and a contact layer -- W<=10 micrometers, W<=2G, and G<=dxtan theta 1 (however, theta1=sin-1 (n2/n1)) -- it comes out and is characterized by a certain thing.
[Claim 2] It is the GaN system semiconductor photo detector which has a photodetection layer which generates a carrier applied to a photocurrent by pn junction of a GaN system material, an up electrode is prepared through the contact layer which consists of a GaN system material for forming an electrode in an upper part side of a photodetection layer by making into an upper part side a side in which light for light-receiving carries out incidence to a photodetection layer, and, for the formation pattern of this up electrode, this electrode is a wrap covering field about the contact layer upper surface. A repeat portion with which an exposed region which this electrode does not cover the contact layer upper surface, but is exposed was located in a line by turns Are the GaN system semiconductor photo detector equipped with the above, and set width of face of each covering field about the direction of a repeat to W, and width of face of each exposed region is set to G. a time of setting [the depth from the contact layer upper surface to a luminous layer] a refractive index of n1 and the external world to n2 for a refractive index of d and a contact layer -- W<=10 micrometers, W<=2G, and G<=dxtan theta 1 (however, theta1=sin-1 (n2/n1)) -- it comes out and is characterized by a certain thing.
[Claim 3] A GaN system semiconductor light emitting device which is characterized by providing the following and which has a luminous layer which consists of a GaN system material A translucency electrode used as a thin film by making into an upper part side a side which light leaves to the external world to a luminous layer so that an up electrode might be prepared through a contact layer which is from a GaN system material for forming an electrode on an upper part side of a luminous layer and this up electrode might penetrate light from a luminous layer A portion with which an electrode for trunks formed so that larger current than current which flows in the direction of an electrode forming face might flow the inside of this translucency electrode in said direction was located in a line by turns
[Claim 4] A GaN system semiconductor light emitting device according to claim 3 whose translucency electrode is an ohmic electrode and whose electrode for trunks is a shot key electrode.
[Claim 5] A GaN system semiconductor light emitting device according to claim 3 by which a

current blocking layer which can serve as active jamming of current is formed in a part which touched this electrode directly under an electrode for trunks in the interior of a contact layer, or a part distant from this electrode directly under the above-mentioned electrode for trunks.
[Claim 6] A GaN system semiconductor photo detector which has a photodetection layer which is characterized by providing the following, and which generates a carrier applied to a photocurrent by pn junction of a GaN system material A translucency electrode used as a thin film by making into an upper part side a side in which light for light-receiving carries out incidence to a photodetection layer so that an up electrode might be prepared through a contact layer which is from a GaN system material for forming an electrode on an upper part side of a photodetection layer and this up electrode might penetrate light for light-receiving A portion with which an electrode for trunks formed so that larger current than current which flows in the direction of an electrode forming face might flow the inside of this translucency electrode in said direction was located in a line by turns
[Claim 7] It is the GaN system semiconductor light emitting device which has a luminous layer which consists of a GaN system material, an up electrode is prepared through a contact layer which is from a GaN system material for forming an electrode on an upper part side of a luminous layer by making into an upper part side a side which light leaves to the external world to a luminous layer, and, for a formation pattern of this up electrode, this electrode is a wrap covering field about the contact layer upper surface. A repeat portion with which an exposed region which this electrode does not cover the contact layer upper surface, but is exposed was located in a line by turns It is the GaN system semiconductor light emitting device equipped with the above, and is characterized by establishing a crevice in an exposed region, while on the upper surface of a contact layer.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] This invention belongs to the technical field of a semiconductor light emitting device and a photo detector which used the GaN system semiconductor material.
[0002]
[Description of the Prior Art] A GaN system light emitting device is a semiconductor light emitting device which used the GaN system material, research is actively done on light emitting diode (LED) of high brightness being realized in recent years, and the report of the room temperature continuous oscillation of semiconductor laser is also heard. A GaN system means the compound semiconductor expressed with Ina Gab Alc N (0<=a<=1, 0<=b<=1, 0<=c<=1, a+b+c=1).
[0003] Hereafter, on these specifications, as that by which a crystal substrate is located in a lower layer side, and a GaN system crystal layer is accumulated upwards on this for explanation of an element, distinction of the vertical direction is prepared in the laminated structure of an element, and phrases, such as the "upper layer", the "upper surface", and the "upper part", are used.
[0004] The general structure of a GaN system light emitting device has the structure where the layered product 20 of the GaN system crystal layer containing the luminous layer 22 by pn junction was grown up on the crystal substrate 10, as shown in drawing 8 . The up electrode P10 (usually p mold) is formed on it as a contact layer for an electrode to form an ohmic electrode for the crystal layer of the maximum upper layer of a layered product 20. Moreover, since a crystal substrate (sapphire crystal substrate) is usually insulation, the lower electrode which is below a luminous layer removes a part of layered product 20, and exposes the lower contact layer 21 partially, and the lower electrode P20 (usually n mold) is formed in the field.
[0005] When making the light emitted from the luminous layer emit up, the mode of a comb (comb) form pattern as shown in drawing 8 (b), and a translucency electrode as shown in drawing 8 (c) is mentioned as a gestalt pattern of an up electrode. Drawing 8 (b) It goes away, and it is one mode of structure which prepared the electrode partially on the luminescence side, and the electrode of a form pattern diffuses current and has structure which takes out the light which emitted light from opening without an electrode. The translucency electrode of drawing 8 (c) forms an electrode material in the shape of a thin film, gives translucency, and has structure which takes out luminescence directly under an electrode outside through a translucency electrode. On the other hand, all are the configurations which were going to emit much light to the exterior from the field which forms an up electrode, though more and the current which flows in a layered product is extended more.
[0006] On the other hand, also in the structure of the GaN system photo detector of the type which takes out the photoelectromotive force by pn junction, the electrode (up electrode) of the side to which incidence of the light for light-receiving is carried out may be made into the electrode of a radial fin type pattern, and the mode of a translucency electrode. On the other hand, this is the configuration that it is going to collect more efficiently many photoelectromotive

force generated in internal pn junction, though each tends to carry out incidence of much light for light-receiving widely into an element from the field which forms an up electrode.
[0007]
[Problem(s) to be Solved by the Invention] However, there is [as opposed to / at the conventional GaN system light emitting device and a GaN system photo detector / the width of face or the inter-electrode gap of an electrode] no numerical convention in any way. For example, in a light emitting device, with the structure of an up electrode partially established like the electrode of a radial fin type pattern, current flows only directly under an electrode mostly, but luminescence by the luminous layer becomes only directly under an electrode. therefore -- right above [of the portion which emits light most strongly even if it is the mode of the electrode of a radial fin type pattern] -- the conductor of an electrode -- the time of a portion existing and taking out light up -- the conductor of an electrode -- it will be said by reflection and absorption in a portion that ejection effectiveness is bad.
[0008] In a light emitting device, in the mode using a translucency electrode, in order to secure translucency, it is necessary to stop the thickness to the minimum. However, if thickness becomes small, since the sheet resistance of the electrode will increase, the voltage drop in an electrode will become large. If sheet resistance becomes extremely large, current will not fully spread in the direction which a field extends, but will stop moreover, emitting light partially as a result. Moreover, although sheet resistance will become small if electrode layer thickness is enlarged at reverse, the ejection effectiveness to the exterior of light where translucency fell and emitted light will worsen.
[0009] Moreover, in a photo detector, with the electrode of a radial fin type pattern, if an outcrop (electrode spacing) is too narrow, sensitivity will worsen, if too conversely large, loss will be received in taking out a generation of carriers to an electrode, and sensitivity will worsen. Moreover, in a translucency electrode, if thickness is made thin in order to put in more light for light-receiving in an element, the sheet resistance of the electrode increases and minute amount current cannot be brought together in high density. Conversely, although sheet resistance will become small if electrode layer thickness is enlarged, translucency falls and the amount of incidence of the light for light-receiving decreases.
[0010] The technical problem of this invention is offering the element which has improved the structure of the electrode of the side which takes out light and was more excellent in the luminescence property in a GaN system light emitting device.
[0011] Moreover, other technical problems of this invention are offering the element which has improved the structure of the electrode of the side which takes in light and was more excellent in the light-receiving property in a GaN system photo detector.
[0012]
[Means for Solving the Problem] A GaN system semiconductor light emitting device of this invention and a GaN system semiconductor photo detector have the following features.
It is the GaN system semiconductor light emitting device which has a luminous layer which consists of a GaN system material, and a side which light leaves to the external world to a luminous layer is made into an upper part side. (1) To an upper part side of a luminous layer An up electrode is prepared through a contact layer which consists of a GaN system material for forming an electrode. A formation pattern of this up electrode An exposed region which this electrode does not cover the contact layer upper surface, and a wrap covering field and this electrode do not cover the contact layer upper surface, but is exposed is the formation pattern which has a repeat portion located in a line by turns, and it sets into said repeat portion. When setting width of face of each covering field about the direction of a repeat to W, setting width of face of each exposed region to G and setting [the depth from the contact layer upper surface to a luminous layer] a refractive index of n1 and the external world to n2 for a refractive index of d and a contact layer, W<=10 micrometers, W<=2G, G<=dxtan theta 1 (however, theta1=sin-1 (n2/n1)), a GaN system semiconductor light emitting device that comes out and is characterized by a certain thing.
[0013] (2) Are the GaN system semiconductor photo detector which has a photodetection layer which generates a carrier applied to a photocurrent by pn junction of a GaN system material, and

make into an upper part side a side in which light for light-receiving carries out incidence to a photodetection layer. An up electrode is prepared through a contact layer which is from a GaN system material for forming an electrode on an upper part side of a photodetection layer. A formation pattern of this up electrode An exposed region which this electrode does not cover the contact layer upper surface, and a wrap covering field and this electrode do not cover the contact layer upper surface, but is exposed is the formation pattern which has a repeat portion located in a line by turns, and it sets into said repeat portion. When setting width of face of each covering field about the direction of a repeat to W, setting width of face of each exposed region to G and setting [the depth from the contact layer upper surface to a luminous layer] a refractive index of n1 and the external world to n2 for a refractive index of d and a contact layer, W<=10 micrometers, W<=2G, G<=dxtan theta 1 (however, theta1=sin-1 (n2/n1)), a GaN system semiconductor photo detector that comes out and is characterized by a certain thing.
[0014] It is the GaN system semiconductor light emitting device which has a luminous layer which consists of a GaN system material, and a side which light leaves to the external world to a luminous layer is made into an upper part side. (3) To an upper part side of a luminous layer A translucency electrode used as a thin film so that an up electrode might be prepared through a contact layer which consists of a GaN system material for forming an electrode and this up electrode might penetrate light from a luminous layer, A GaN system semiconductor light emitting device to which an electrode for trunks with which passage of larger current than this translucency electrode in the direction of an electrode forming face was enabled is characterized by having a portion located in a line by turns.
[0015] (4) A GaN system semiconductor light emitting device of the above-mentioned (3) publication whose translucency electrode is an ohmic electrode and whose electrode for trunks is a shot key electrode.
[0016] (5) contact -- a layer -- the interior -- it can set -- a trunk -- ** -- an electrode -- directly under -- this -- an electrode -- having touched -- a part -- or -- the above -- a trunk -- ** -- an electrode -- directly under -- this -- an electrode -- from -- having separated -- a part -- current -- active jamming -- becoming -- obtaining -- current -- a blocking layer -- forming -- having -- **** -- the above -- (-- three --) -- a publication -- GaN -- a system --

[0017] (6) Are the GaN system semiconductor photo detector which has a photodetection layer which generates a carrier applied to a photocurrent by pn junction of a GaN system material, and make into an upper part side a side in which light for light-receiving carries out incidence to a photodetection layer. A translucency electrode used as a thin film so that an up electrode might be prepared through a contact layer which is from a GaN system material for forming an electrode on an upper part side of a photodetection layer and this up electrode might penetrate light for light-receiving, A GaN system semiconductor photo detector to which an electrode for trunks with which passage of larger current than this translucency electrode in the direction of an electrode forming face was enabled is characterized by having a portion located in a line by turns.
[0018] It is the GaN system semiconductor light emitting device which has a luminous layer which consists of a GaN system material, and a side which light leaves to the external world to a luminous layer is made into an upper part side. (7) To an upper part side of a luminous layer An up electrode is prepared through a contact layer which consists of a GaN system material for forming an electrode. A formation pattern of this up electrode It is the formation pattern which has a repeat portion with which an exposed region which this electrode does not cover the contact layer upper surface, and a wrap covering field and this electrode do not cover the contact layer upper surface, but is exposed was located in a line by turns. A GaN system semiconductor light emitting device characterized by establishing a crevice in an exposed region while on the upper surface of a contact layer.
[0019] A GaN system means a compound semiconductor shown by Ina Gab Alc N (0<=a<=1, 0<=b<=1, 0<=c<=1, a+b+c=1).
[0020]
[Function] In the mode of the light emitting device of the above (1), W, G, d, n1, and n2 are

specified as **W<=10micrometer, **W<=2G, and **G<=dxtan theta 1 like the above (1) in the repeat portion (portion which is specifically equivalent to "the gear tooth of a comb" of the electrode of a radial fin type pattern) of an up electrode. When limitation of these **s - ** gathers, reflection and absorption with an electrode are suppressed in the light emitted from the luminous layer to the minimum, and optical ejection effectiveness improves. Drawing 2 explains this briefly.
[0021] Limitation with the above-mentioned ** and ** limits the desirable size relation of the ratio of a covering field and an exposed region while carrying out numerical limitation of the covering field (width of face of an electrode P1). The numerical range where the magnitude of the inlet of current is desirable is limited first, limitation of the above-mentioned ** is added to this by limitation of the above-mentioned **, and the relation between the numerical range where the magnitude of emission opening of light is desirable, and the inlet of current is limited. In the above-mentioned **, in 2 G<W, the field which takes out light outside by the up p cladding layer becomes small, that is, external ejection effectiveness worsens, and it is not desirable.
[0022] By limitation of the above-mentioned ** and **, the relation between a opening desirable for light and a failure left in the external world is decided, and light occurs in the portion which moreover separated only d from the failure to directly under. After arranging this condition, limitation of the above-mentioned ** is added. This is the desirable relation of d and G based on law of refraction, as shown in drawing 2 . The light L1 emitted from the luminous layer to which only d is separated and located in directly under from an up electrode inferior surface of tongue has angle of refraction theta 1, and leaves it in the external world from a GaN system crystal layer. At this time, the light L1 emitted from m1 (directly under [electrode center]) before m2 (directly under [electrode edge]) in drawing 2 can be taken out outside throughout the upper surface (field of G) of a layer S3 by considering as G<=dxtan theta 1. On the upper surface on the left of it, total reflection is carried out and light does not come out.
[0023] In the mode of the photo detector of the above (2), W, G, d, n1, and n2 like the above (2) By specifying W, G, d, n1, and n2 as **W<=10micrometer, **W<=2G, and **G<=dxtan theta 1 (however, theta1=sin-1 (n2/n1)), the carriers which could fully secure the amount of the light to a photodetection layer, and were generated can be collected efficiently, and sensitivity improves.

[0024] In the mode of the light emitting device of the above (3), by arranging a translucency electrode and the electrode for trunks by turns, the voltage drop in the luminous layer upper part can be suppressed to the minimum, and current can be spread over the whole translucency electrode through the electrode for trunks. Consequently, current fully flows throughout a luminous layer and the whole surface emits light.
[0025] Further in addition to the mode of the light emitting device of the above (3), by controlling the current which flows directly between the electrode for trunks, and a contact layer as a mode of the above (4) and (5) Since current does not flow directly under [for trunks] an electrode but a current path is flowed directly under a translucency electrode to drawing 6 (a) and (b) as an arrow head shows, the ejection effectiveness from the translucency electrode of the light which emitted light becomes good.
[0026] In the mode of the photo detector of the above (6), by arranging a translucency electrode and the electrode for trunks by turns, the current generated directly under the translucency electrode can be promptly brought together in the electrode for trunks after a carrier beam with a translucency electrode, and a speed of response and sensitivity improve.
[0027] In the mode of the light emitting device of the above (7), by having established the crevice in the exposed region of the inside on the upper surface of a contact layer by the side of the upper part, the thickness of the layer to a luminous layer becomes thin, it can prevent that the light emitted from the luminous layer declines in a contact layer, and optical ejection effectiveness becomes high. By this, even when making luminescence wavelength in a luminous layer into ultraviolet rays like 350nm, GaN can be used for p mold contact layer. On the other hand, about the electrode lower part, since the thickness of the layer to a luminous layer is secured thickly enough, it can prevent the fall of the life by electrode material being spread to a luminous layer.

[0028]
[Embodiment of the Invention] First, the mode of the light emitting device of the above (1) is explained. Drawing 1 is drawing showing the example of a configuration of the light emitting device of the above (1), and shows the GaN system light emitting diode (LED) which has double heterojunction structure (DH structure) as a luminous layer. Although p mold and a lower electrode are hereafter explained for an up electrode as an n mold using the example of a configuration into which the GaN system crystal layer was grown up on silicon on sapphire in case element structure is explained, the upper and lower sides of p mold and n mold may combine freely the mode of reverse, the mode which changed the location of an electrode using the crystal substrate with which it has conductivity by not being limited to this.
[0029] In the example of this drawing, as shown in drawing 1 (a), a buffer layer (not shown) is minded on the crystal substrate 1. The n mold GaN layer S1 which serves both as n mold contact layer and n mold cladding layer, the InGaN barrier layer S2, and the p mold GaN layer S3 which serves both as p mold contact layer and p mold cladding layer are formed. It has structure which one corner of this layered product was partially etched, and the n mold GaN layer S1 exposed. The lower electrode (n mold electrode) P2 is formed in this exposed n mold GaN layer S1, and the up electrode (p mold electrode) P1 is formed in the maximum upper surface of the layered product left behind by etching.
[0030] The formation pattern of the up electrode P1 serves as an electrode of a radial fin type pattern, as shown in drawing 1 (b), on the upper surface of a contact layer, the field covered with the portion equivalent to "the gear tooth of a comb" is a covering field, and the portion equivalent to the gap of "the gear tooth of a comb" is an exposed region. The covering field and the exposed region serve as a repeat portion located in a line by turns in the shape of stripes. Partial P1a which projected among the up electrodes P1 is an electrode for bondings used for wire bonding. It is drawing 2 which expanded the repeat portion among the A-A cross sections of the up electrode shown in drawing 1 (b). As shown in drawing 2 , as explanation of the above-mentioned operation described, limitation of ** - ** is made using [an inter-electrode gap / the refractive index of G and a contact layer] distance from n2 and p mold contact layer upper surface to a luminous layer as d for the refractive index of n1 and the external world (usually atmospheric air) using electrode width of face as W.
[0031] The formation pattern of the electrode of a repeat portion may be a radial fin type pattern, and the other shape of circular [of the shape of a grid as shown in drawing 3 (a), and this heart as shown in drawing 3 (b)], and a concentric circle etc. should just be the patterns which a covering field and an exposed region repeat by turns. Moreover, it may be the same period, and as long as it not only repeats, but is within the limits of limitation of the above-mentioned ** - **, a covering field and an exposed region may be the patterns which change regularly or irregularly and are arranged by turns.
[0032] Although the thickness of the repeat portion of an up electrode is not limited, since it will become the failure of passage of light if too thick, 0.01 micrometers - about 2 micrometers are a desirable range. Moreover, if translucency is given to an up electrode, since luminescence can be taken out through an electrode, it is desirable.
[0033] In order that an electrode material may control the voltage drop in an electrode / semiconductor layer interface, the material of ohmic nature is good and may use a well-known material. For example, the mode using one or more simple substances or a laminated structure, and an alloy is mentioned out of Au, nickel, Pt, Pd, Ir, Co, C, etc.
[0034] As structure related to the mechanism of luminescence in a light emitting device, the structure of having SQW (Single Quantum Well) which has a superstructure besides by two-layer [by simple pn junction] (HOMO, SH) and DH (double heterojunction) three layers, MQW (Multiple Quantum Well), and a quantum dot etc. is mentioned directly. The luminous layer as used in the field of this invention in this is a depletion layer which is produced in the interface of cementation in the case of two-layer pn junction, and is a barrier layer in DH. moreover, the case of SQW, MQW, and quantum dot structure -- a barrier layer and a well -- the whole structure of the square well potential containing a layer is a luminous layer.
[0035] The distance d from p mold contact layer upper surface to a luminous layer is the

distance from the contact layer upper surface to the upper surface of a barrier layer, when a luminous layer is a barrier layer. Moreover, the luminous layer also of the case of SQW, MQW, and quantum dot structure is the distance from the contact layer upper surface to the upper surface of square well potential structure, i.e., the upper surface of the maximum upper layer of the barrier layers. Only when making into a luminous layer the depletion layer produced in the interface of two-layer pn junction, distance from the contact layer upper surface to the interface of pn junction is set to d in approximation.
[0036] While constitutes the GaN system crystal layer prepared independently and the layer used also [cladding layer] like drawing 1 , and pn junction, and a contact layer may be a layer, in order to form an ohmic electrode. Even if it is which case, the material of a bigger band gap than this light is used so that light from a luminous layer may not be absorbed.
[0037] Although the refractive index n1 of a contact layer changes also with materials of a contact layer, it becomes 2.426 etc. by 2.493 and aluminum0.1 Ga0.9 N, for example to light with a wavelength of 450nm at GaN. The refractive index n2 of the external world is a refractive index of the portion (a vacuum or material) which surround the outside as an interface of refraction by the contact layer upper surface. In use in the atmospheric air which is the most general operating environment, it is set to refractive-index n2=1 of air.
[0038] Although a GaN system material is used for the material of a contact layer, it is good to make it not make light absorb using the material of a bigger band gap than the luminous energy emitted from the luminous layer. For example, in ultraviolet-rays luminescence, big AlGaN of a band gap is desirable. However, if aluminum presentation is made high, a luminescence lateral electrode will stop being able to acquire an ohmic property easily.
[0039] An ohmic electrode is desirable, contact of a metal-semiconductor does not show a rectifying characteristic and a publication of S.M.Sze work (Yasuo Nam II translations) "a semiconductor device" and Sangyo Tosho Publishing (the 3rd ** of the first edition, 163 pages) is referred to.
[0040] the method of growing up a GaN system crystal -- HVPE, MOCVD, and MBE -- law etc. mentions -- having -- especially -- MOCVD-MBE -- law is desirable.
[0041] About the mode of the photo detector of the above (2), the structure as an element is the same as that of drawing 1 . Moreover, explanation of each part, such as an up electrode and p mold contact layer, applies explanation of the above (1) correspondingly noting that a luminous layer is used as a photodetection layer and the light for light-receiving from the external world carries out incidence into an element from the exposed region on the upper surface of a contact layer.
[0042] Next, the mode of the light emitting device of the above (3) is explained. About the laminated structure of the whole element, except the structure of an up electrode, it is the same as that of the light emitting device of the above (1), and the structure of drawing 1 (a), the structure of the conventional element of drawing 8 , etc. are referred to. The up electrode P1 of this light emitting device has the portion located in a line while contacting so that the translucency electrode P11 and the electrode P12 for trunks might be in switch-on mutually by turns as shown in drawing 5 (a). The translucency electrode P11 is an electrode used as the thin film so that the light from a luminous layer might be penetrated. The electrode P12 for trunks is the electrode with which passage of larger current than the current which flows in the direction of a field in this direction was enabled in the inside of the translucency electrode P11, i.e., the smaller electrode for current supply sources of sheet resistance. The direction of a field is a direction which an electrode forming face (upper surface of a contact layer) extends. Moreover, the laminated structures of the GaN system crystal layer shown in drawing 5 (a) are n mold cladding layer S1, a barrier layer S2, and p mold cladding layer (= contact layer) S3.
[0043] In order to control the voltage drop in an electrode / semiconductor layer interface, the material of a translucency electrode has the good material of ohmic nature, and the material shown by the light emitting device of the above (1) can be used for it. The thickness of a translucency electrode has 0.005 micrometers - desirable 0.05 micrometers, in order to secure translucency.
[0044] Although the material itself may use the same thing as a translucency electrode, the

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electrode for trunks is formed so that larger current than the flowing current can pass a translucency electrode, namely, so that lower [sheet resistance] than a translucency electrode. In order to mention the mode formed concrete more thickly and to secure sufficient amount of current in that case, 0.01 micrometers - 2 micrometers are desirable.
[0045] The formation pattern of the electrode for trunks and a translucency electrode, i.e., the mutual combination pattern in the contact layer upper surface, is not limited. In the example shown in drawing 5 (b), the electrode P12 for trunks roughly divided the contact layer upper surface into the partition of three squares, and the translucency electrode P11 is formed in the partition of each square. In addition, it is good also as a pattern which drawing 1 (b) Went away, used the pattern of the electrode for trunks as patterns, such as the shape of a mold and a grid of drawing 3 (a), circular [of this heart of drawing 3 (b)], the shape of a circle of this heart, and a radial, and prepared the translucency electrode in the gap of each electrode for trunks. Luminescence may become homogeneity, if each electrode for trunks is arranged so that distance may become the same to the n electrode P2 as especially shown in drawing 4 (a) and drawing 4 (b). Moreover, W<=10 micrometers and W<=2G may be applied among the limited conditions of the up electrode of the light emitting device of the above (1).
[0046] As explanation of the above-mentioned operation described, in this light emitting device of (3), the current which flows directly between the electrode for trunks and a contact layer is controlled, and the mode which passes current under the translucency electrode is mentioned. Concretely, in order to control current, as the electrode for trunks is shown in the mode and drawing 6 (b) which are made into the thing of shot key nature, the mode which forms the current blocking layer Q which can serve as active jamming of current directly under the electrode for trunks in the interior of the contact layer S3 is mentioned. the current blocking layer Q may be formed in the part which could prepare in contact with the electrode (that is, it exposes to the contact layer upper surface -- making), and is distant from this electrode directly under the electrode for trunks.
[0047] What is necessary is in the case of p type layer, to choose a simple substance or two or more materials, and just to use them out of aluminum, Ti, Ta, Si, etc., in order to form the electrode for trunks as shot key nature. Although the formation method of a shot key nature electrode is not limited, after forming a translucency electrode and giving this ohmic nature in electrode annealing, the procedure which forms the electrode for trunks as a shot key electrode is desirable.
[0048] A current blocking layer is partially prepared as a condition which considered as the condition of having exposed to the contact layer upper surface, as mentioned above, or was laid underground in the contact layer. a mode, undoping, etc. which are used as a different conductivity type (it is n mold in the case of p mold contact layer) from the perimeter in order to acquire an operation of current inhibition -- high -- the mode used as a GaN system crystal layer [****], the mode using insulating materials (for example, SiO2, Si3 N4, aluminum 2O3, etc.), etc. are mentioned.
[0049] About the mode of the photo detector of the above (6), the laminated structure as an element is the same as that of drawing 1 . About the structure of an up electrode, explanation of the light emitting device of the above (3) is applied correspondingly. However, since it is a photo detector, the mode which makes the electrode for trunks shot key nature unlike the light emitting device of the above (3), the mode which prepares a current blocking layer directly under the electrode for trunks are unnecessary. Moreover, a pin structure type or the pn junction type of element structure is sufficient as the photo detector of the above (2), and the photo detector of the above (6). You may be another structure if the intention of invention is filled.
[0050] Next, the mode of the light emitting device of the above (7) is explained. About the laminated structure of the whole element, except the structure of an up electrode and a contact layer, it is the same as that of the light emitting device of the above (1) and (3), and these explanation is applied correspondingly. The structure of drawing 1 (a), the structure of the conventional element of drawing 8 , etc. are referred to. A structural feature is not only in an up electrode but in a contact layer at this light emitting device. That is, like the case of the light emitting device of the above (1), a covering field and an exposed region are the formation

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patterns which have the repeat portion located in a line by turns, and the formation pattern of an up electrode is characterized by establishing the crevice S32 in the exposed region on the upper surface S31 (the alternate long and short dash line shows) of p mold contact layer (=p mold cladding layer) S3, as shown in drawing 7 .
[0051] Although there is no convention also in thickness, since it will become possible [ejection] also for luminescence from directly under [of an up electrode] if it is made the thickness which is the degree which light penetrates, it is [that an up electrode should just be an ohmic electrode] desirable. The formation pattern of an up electrode drawing 1 (b) Goes away, and patterns, such as the shape of a mold and a grid of drawing 3 (a), circular [of this heart of drawing 3 (b)], the shape of a circle of this heart, and a radial, are mentioned.
[0052] Although the thickness of p mold contact layer shown in drawing 7 , i.e., the thickness of the portion which is not a crevice, is not limited, it is good for the degree which does not cause the element life fall by electrode material being spread in a luminous layer to thicken. On the other hand, since there are problems, like slot formation takes time amount when a contact layer is too thick, the range which is 0.1 micrometers - about 5 micrometers is good.
[0053] Although a crevice is established in an exposed region among the upper surfaces S31 of p mold contact layer S3, it is desirable to prepare so that this field may be occupied more greatly. Therefore, the gestalt of a crevice will be in the condition that the slot was located in a line in the shape of stripes, the condition that the single shot-hole distributed, etc., according to the configuration of an exposed region.
[0054] The thickness from the base of a crevice to the upper surface of a luminous layer is so good that it is thin in order to make [many] the amount of ejection of the light from a light-emitting part. That is, a crevice may be formed so deeply that the barrier layer upper surface is arrived at. However, if the formation production process of a crevice is taken into consideration, and a crevice is too deep, the yield at the time of formation will worsen.
[0055] the width of face of the electrode of the portion which is equivalent to "the gear tooth of a comb" although the size of a repeat portion is based on the scale of a light emitting device etc. when using an up electrode as the pattern of the Cush form -- 0.1 micrometers - about 10 micrometers -- carrying out -- a conductor -- it is desirable to set width of face of the crevice between between to 0.1 micrometers - 10 micrometers.
[0056] although what kind of method is sufficient as the crevice forming method, if the controllability at the time of etching is considered -- reactive ion etching (RIE) -- law is most alike and is mentioned. In case this RIE is performed, a mask is used so that it may not etch except a crevice, but when the luminescence lateral electrode itself is used as a mask, a production process can be simplified and it is very good. Furthermore, it is good to control to the degree from which the thickness of the electrode used as mask material becomes transparent at the time of etching termination.
[0057]
[Example] In example 1 this example, the thing of the structure shown in drawing 1 as a light emitting device of the above (1) was actually manufactured.
[A crystal substrate and buffer layer] The sapphire C side crystal substrate was used as a crystal substrate. This substrate has been first arranged in an MOCVD system, the temperature up was carried out to 1100 degrees C under the hydrogen ambient atmosphere, and thermal etching was performed. after that nitrogen-gas-atmosphere mind -- changing -- temperature -- to 500 degrees C, ammonia was grown up in trimethylgallium (henceforth, TMG) as a lowering raw material, and the sink and the GaN low-temperature buffer layer were grown up as an N raw material.
[0058] [DH structure] The temperature up of the temperature was carried out to 1000 degrees C, and 3 micrometers of n mold GaN layers S1 which are n mold contact layer [in / for a silane / in TMG and ammonia / a sink and drawing 1 (a)] (n mold cladding layer) as a dopant as a raw material were grown up. Then, the sink and the In0.2 Ga0.8 N barrier layer S2 were formed for trimethylindium (TMI), TMG, ammonia, and a silane. Furthermore, 5.0-micrometer (=d) growth of the p mold GaN layer S3 which are a sink and p mold contact layer (p mold cladding layer) about TMG and ammonia bis(cyclopentadienyl) magnesium (Cp2Mg) was carried out. The

controlled atmosphere was annealed to the switch room temperature to nitrogen after that, and the sample was produced.
[0059] It is SiO2 with a thickness of 2000A by the spatter to the upper surface of after growth and p mold contact layer S3. The film was formed, 5.5 micrometers was etched until it carried out patterning formation of the photoresist by the photolithography and n mold contact layer S1 was partially exposed on it with dry etching, and it considered as the laminated-structure object as shown in drawing 1 (a).
[0060] [Formation of an electrode] SiO2 on the upper surface of p mold contact layer To the film, the pattern of a comb mold was formed with photolithography technology, and Au layer with a thickness of 1000A was formed nickel layer with a thickness of 500A and on it by electron beam evaporation. And by lift off, it considered as the electrode P1 of a comb mold pattern. The electrode width of face (width of face W of a covering field) of the portion of "the gear tooth of a comb" at this time was 2 micrometers, and the inter-electrode gap (width of face G of an exposed region) was 2 micrometers. Similarly, aluminum layer with a thickness of 2300A was formed Ti layer with a thickness of 200A and on it as an n mold electrode P2. Furthermore, in order to obtain the ohmic nature of each electrode, 600 degree-Cx10min electrode annealing was carried out.
[0061] Like the above, bonding electrode P1a of the up electrodes P1 formed Au layer with a thickness of 1500A nickel layer with a thickness of 500A and on it, and formed it by lift off. This sample was divided for the chip and the GaN system LED was obtained as a light emitting device of the above (1).
[0062] The obtained light emitting devices are W= 2 micrometers, G= 2 micrometers, and d= 5.0 micrometers, and have satisfied W<=10 micrometers, W<=2G, and G<=dxtan theta 1 (however, theta1=sin-1 (1/2.493)). When this LED was mounted on the To-18 stem base and the output was measured, by the wavelength of 450nm, and 20mA, it is 2.5mW and the high radiant power output was obtained on the same current and voltage compared with the conventional light emitting device as shown in drawing 8 .
[0063] In example 2 this example, the same light emitting device as an example 1 was formed except having set electrode width of face (width of face W of a covering field) of the portion of "the gear tooth of a comb" of a radial fin type pattern to 1 micrometer, and having set the inter-electrode gap (width of face G of an exposed region) to 1 micrometer. The obtained light emitting devices are W= 1 micrometer, G= 1 micrometer, and d= 5.0 micrometers, and have satisfied W<=10 micrometers, W<=2G, and G<=dxtan theta 1 (however, theta1=sin-1 (1/2.493)).
[0064] When this LED was mounted on the To-18 stem base and the output was measured, by the wavelength of 450nm, and 20mA, it is 3.0mW and it turned out that luminescence reinforcement is equivalent compared with the light emitting device of an example 1.
[0065] In example 3 this example, the thing of the laminated structure shown in drawing 1 (a) as a light emitting device of the above (3) and the up electrode structure shown in drawing 5 was actually manufactured. [The 0066] as an example 1 [same up to the laminating of a crystal substrate, a buffer layer, and the GaN system crystal layers S1, S2, and S3] [Translucency electrode] The translucency electrode was produced on p mold contact layer (=p mold cladding layer) S3. First, the pattern for the electrode for trunks formed at an after production process with photolithography technology was formed, and Au layer with a thickness of 25A was formed nickel layer with a thickness of 25A and on it by electron beam evaporation. And the translucency electrode from which the pattern of the electrode for trunks escaped by lift off was formed. The pattern of the electrode for trunks is as being shown in drawing 5 (b). Similarly, aluminum layer with a thickness of 2300A was formed Ti layer with a thickness of 200A and on it as an n mold electrode P2. Furthermore, in order to obtain the ohmic nature of each electrode, 600 degree-Cx10min electrode annealing was carried out.
[0067] Patterning of the electrode for trunks was carried out with photolithography technology, it carried out the laminating of the aluminum layer with a thickness of 2300A Ti layer with a thickness of 200A and on it by electron beam evaporation, and formed it by lift off. The width of face of the electrode for trunks was larger than the width of face of the slot established in said translucency electrode, and the flank of the electrode for trunks runs aground on the upper

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surface of a translucency electrode, a part laps, and it was made to fully flow mutually, as shown in drawing 6 (b).
[0068] Like the example 1, bonding electrode P1a of the up electrodes P1 formed Au layer with a thickness of 1500A nickel layer with a thickness of 500A and on it, and formed it by lift off. This sample was divided for the chip and the GaN system LED was obtained as a light emitting device of the above (3).
[0069] When this LED was mounted on the To-18 stem base and the output was measured, by the wavelength of 450nm, and 20mA, it was 3.0mW, and compared with LED of only the conventional transparent electrode without the electrode for trunks, forward voltage fell, uniform luminescence was obtained in the field, and the radiant power output improved.
[0070] At example 4 this example, it is SiO2 as a current blocking layer to the surface of p mold contact layer directly under the electrode for trunks. The light emitting device was formed like the example 3 except having formed the layer. SiO2 A layer is SiO2 by photolithography technology, the spatter, and lift off, before forming a translucency electrode. It formed so that the upper surface of a layer and the upper surface of p mold contact layer might become the same.
[0071] It divided for the chip and the GaN system LED as a variation of the light emitting device of the above (3) was obtained. When this LED was mounted on the To-18 stem base and the output was measured, by the wavelength of 450nm, and 20mA, it is 3.0mW and equivalent luminescence reinforcement was obtained compared with LED of an example 3.
[0072] In example 5 this example, the GaN system LED which has the up electrode structure and p mold contact layer structure which are shown in the laminated structure shown in drawing 1 (a) and drawing 7 as a light emitting device of the above (7) was actually manufactured. It is the same production process as an example 1 up to the laminating of a crystal substrate, a buffer layer, and the GaN system crystal layers S1, S2, and S3. However, thickness of the p mold GaN contact layer S3 was set to 0.5 micrometers.
[0073] Etching removal of a part of p mold GaN contact layer S3 and barrier layer S2 was carried out for the obtained sample by dry etching, n mold contact layer S1 was exposed, and n mold electrode P2 was formed.
[0074] Next, it is SiO2 in order to form a crevice S32 in the upper surface S31 of p mold contact layer S3, as shown in drawing 7 . The mask pattern was formed by the film. This mask pattern is a mask pattern which leaves the field which forms an up electrode to a comb mold pattern, and size specification of a radial fin type portion was made into electrode width of face of 2 micrometers, and groove crevice width of face of 4 micrometers. After that, by dry etching, the crevice was investigated from the upper surface S31, and the crevice attained to near the barrier layer upper surface was formed.
[0075] Next, the up electrode was formed in the left-behind upper surface S31 as a comb mold pattern like the example 1. This sample was divided for the chip and the GaN system LED was obtained as a light emitting device of the above (3). When this LED was mounted on the To-18 stem base and the output was measured, by the wavelength of 450nm, and 20mA, it is 2.5mW and it turned out [which do not have a crevice] that it goes away conventionally and optical ejection effectiveness improves compared with LED of the electrode of a form pattern.
[0076] In example 6 this example, the electrode of a radial fin type pattern is formed in p mold contact layer upper surface before crevice formation, and the light emitting device was formed like the example 5 except having used as the Au/nickel electrode itself the mask used for crevice formation. Consequently, it turned out that the same structure as an example 5 carries out simple [of the production process], and can produce it.
[0077]
[Effect of the Invention] Like the above-mentioned explanation, the GaN system light emitting device which was more excellent in the luminescence property, and the GaN system photo detector which was more excellent in the light-receiving property came to be obtained by various improvements of the up electrode structure by this invention.

[Translation done.]

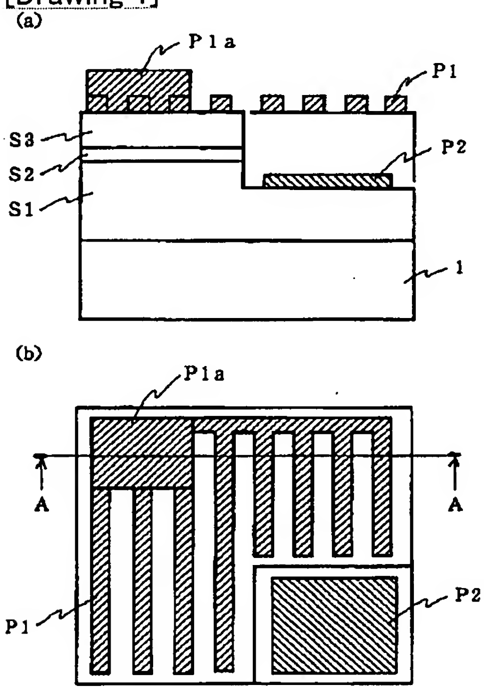
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is drawing showing an example of the structure of the light emitting device GaN system light emitting device by this invention. Moreover, it can refer to also as an example of the structure of the photo detector of this invention.
[Drawing 2] It is drawing expanding and showing a repeat portion among the A-A cross sections of the up electrode shown in drawing 1 (b).
[Drawing 3] It is drawing which illustrates the formation pattern of the repeat portion of an up electrode of the light emitting device by this invention. Moreover, it can refer to also as an example of the formation pattern of the repeat portion of an up electrode of the photo detector by this invention.
[Drawing 4] It is drawing showing other examples of the formation pattern of the repeat portion of an up electrode of the light emitting device by this invention. Moreover, it can refer to also as an example of the formation pattern of the repeat portion of an up electrode of the photo detector by this invention.
[Drawing 5] It is drawing which illustrates the formation pattern of an up electrode of the light emitting device by this invention. Moreover, it can refer to also as an example of the formation pattern of an up electrode of the photo detector by this invention.
[Drawing 6] It is drawing which illustrates other modes of an up electrode of the light emitting device by this invention.
[Drawing 7] It is drawing showing an example of the structure of the up electrode and p mold contact layer of the light emitting device by this invention.
[Drawing 8] It is drawing showing the laminated structure of the conventional GaN system light emitting device, and the pattern of an electrode.
[Description of Notations]
S1 n mold contact layer (cladding layer)
S2 Luminous layer (barrier layer)
S3 p mold contact layer (cladding layer)
L1 Light
P1 Up electrode

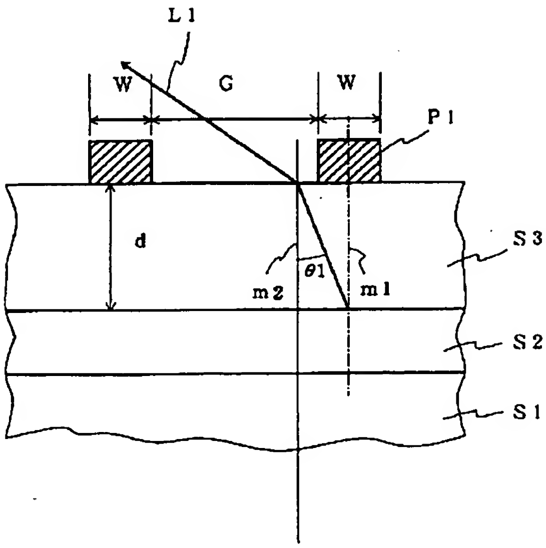
[Translation done.]

DRAWINGS

[Drawing 1]



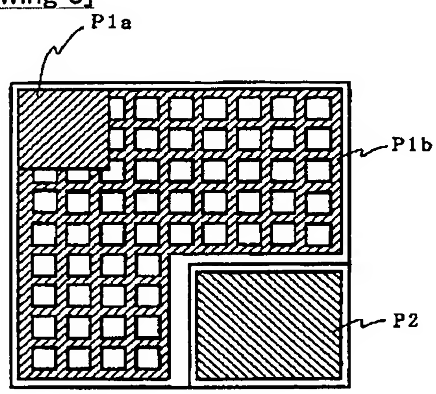
[Drawing 2]



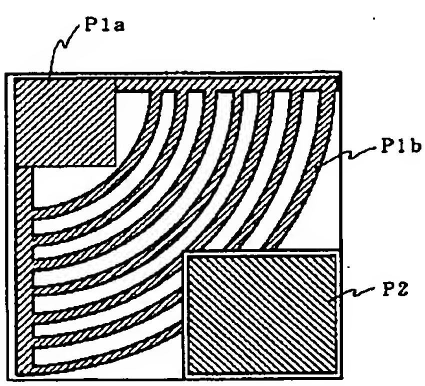
S1　n型コンタクト層（クラッド層）
S2　発光層（活性層）
S3　p型コンタクト層（クラッド層）
L1　光
P1　上部電極

[Drawing 3]

(a)



(b)



[Drawing 4]

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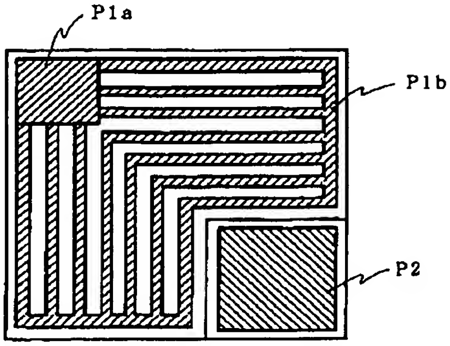
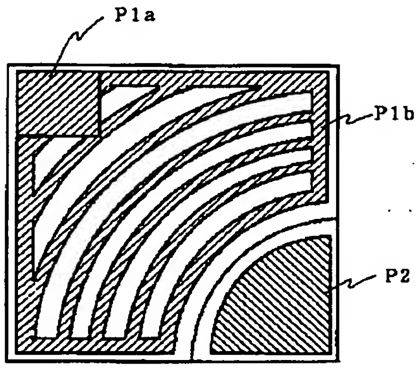
(a)

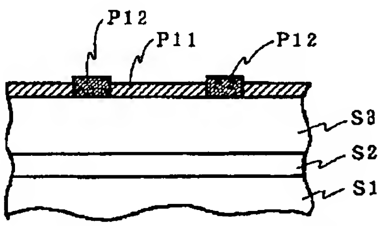


(b)

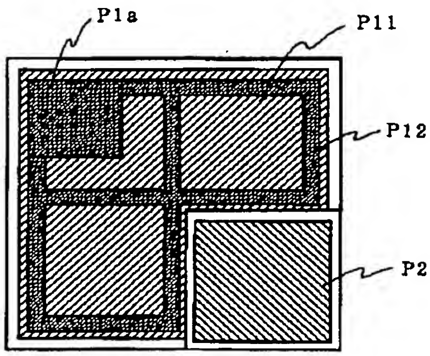


[Drawing 5]

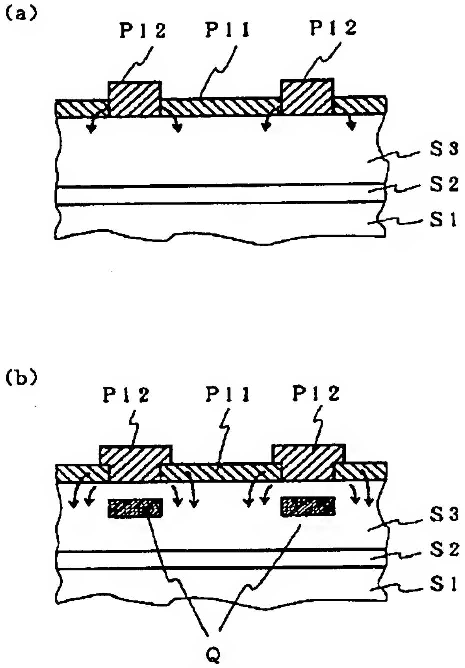
(a)



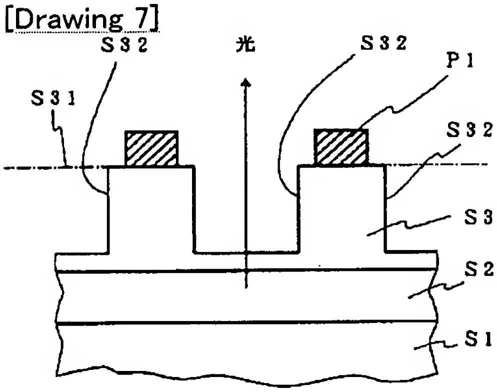
(b)



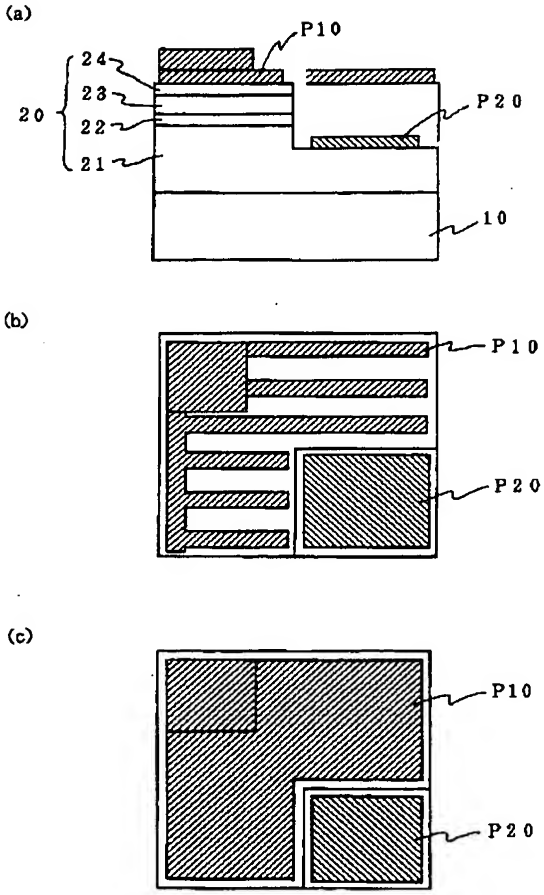
[Drawing 6]



[Drawing 7]



[Drawing 8]



[Translation done.]

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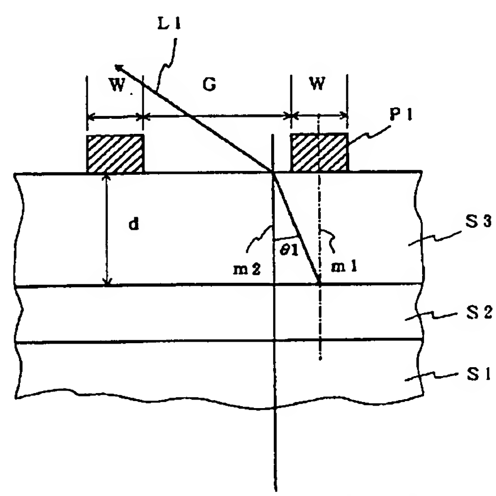
(54)【発明の名称】　ＧａＮ系半導体発光素子およびＧａＮ系半導体受光素子

(57)【要約】
【課題】　光を取り出す側の電極の構造を改善し、より発光特性の優れたＧａＮ系発光素子を提供し、また、光を取り入れる側の電極の構造を改善し、より受光特性の優れたＧａＮ系受光素子を提供すること。
【解決手段】　上部電極Ｐ１の形成パターンを、該電極Ｐ１がコンタクト層Ｓ３の上面を覆う被覆領域と、層Ｓ３の上面を覆わず露出させる露出領域とが交互に並んだ繰り返し部分を有する形成パターンとして、この繰り返し部分において、被覆領域の幅をＷ、露出領域の幅をＧ、コンタクト層Ｓ３の上面から発光層Ｓ２までの深さをｄ、コンタクト層の屈折率をｎ１、外界の屈折率をｎ２として、$W \leq 10\,\mu m$、$W \leq 2G$、$G \leq d \times \tan\theta 1$（ただし、$\theta 1 = \sin^{-1}(n2/n1)$）満足させる。また、その他種々の上部電極の態様を付与する。



Ｓ１　ｎ型コンタクト層（クラッド層）
Ｓ２　発光層（活性層）
Ｓ３　ｐ型コンタクト層（クラッド層）
Ｌ１　光
Ｐ１　上部電極

1

【特許請求の範囲】

【請求項１】　ＧａＮ系材料からなる発光層を有するＧａＮ系半導体発光素子であって、発光層に対し光が外界へ出ていく側を上部側として、発光層の上部側には、電極を形成するためのＧａＮ系材料からなるコンタクト層を介して上部電極が設けられ、
該上部電極の形成パターンは、該電極がコンタクト層上面を覆う被覆領域と、該電極がコンタクト層上面を覆わず露出させる露出領域とが交互に並んだ繰り返し部分を有する形成パターンであって、
前記繰り返し部分において、繰り返しの方向に関する個々の被覆領域の幅をＷとし個々の露出領域の幅をＧとし、コンタクト層上面から発光層までの深さをｄ、コンタクト層の屈折率をｎ１、外界の屈折率をｎ２とするとき、
$W \leq 10\mu m$、
$W \leq 2G$、
$G \leq d \times \tan\theta 1$（ただし、$\theta 1 = \sin^{-1}(n2/n1)$）、
であることを特徴とするＧａＮ系半導体発光素子。

【請求項２】　ＧａＮ系材料のｐｎ接合によって光電流に係るキャリアを発生する光検出層を有するＧａＮ系半導体受光素子であって、光検出層に対し受光対象光が入射する側を上部側として、光検出層の上部側には、電極を形成するためのＧａＮ系材料からなるコンタクト層を介して上部電極が設けられ、
該上部電極の形成パターンは、該電極がコンタクト層上面を覆う被覆領域と、該電極がコンタクト層上面を覆わず露出させる露出領域とが交互に並んだ繰り返し部分を有する形成パターンであって、
前記繰り返し部分において、繰り返しの方向に関する個々の被覆領域の幅をＷとし個々の露出領域の幅をＧとし、コンタクト層上面から発光層までの深さをｄ、コンタクト層の屈折率をｎ１、外界の屈折率をｎ２とするとき、
$W \leq 10\mu m$、
$W \leq 2G$、
$G \leq d \times \tan\theta 1$（ただし、$\theta 1 = \sin^{-1}(n2/n1)$）、
であることを特徴とするＧａＮ系半導体受光素子。

【請求項３】　ＧａＮ系材料からなる発光層を有するＧａＮ系半導体発光素子であって、発光層に対し光が外界へ出ていく側を上部側として、発光層の上部側には、電極を形成するためのＧａＮ系材料からなるコンタクト層を介して上部電極が設けられ、
該上部電極が、発光層からの光を透過し得るように薄膜とされた透光性電極と、該透光性電極中を電極形成面の方向に流れる電流よりも大きい電流が前記方向に流れるよう形成された幹線用電極とが、交互に並んだ部分を有することを特徴とするＧａＮ系半導体発光素子。

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【請求項４】　透光性電極がオーミック電極であって、幹線用電極がショットキー電極である請求項３記載のＧａＮ系半導体発光素子。

【請求項５】　コンタクト層の内部における、幹線用電極の直下で該電極に接した部位に、または上記幹線用電極の直下で該電極から離れた部位に、電流の妨害となり得る電流阻止層が形成されている請求項３記載のＧａＮ系半導体発光素子。

【請求項６】　ＧａＮ系材料のｐｎ接合によって光電流に係るキャリアを発生する光検出層を有するＧａＮ系半導体受光素子であって、光検出層に対し受光対象光が入射する側を上部側として、光検出層の上部側には、電極を形成するためのＧａＮ系材料からなるコンタクト層を介して上部電極が設けられ、
該上部電極が、受光対象光を透過し得るように薄膜とされた透光性電極と、該透光性電極中を電極形成面の方向に流れる電流よりも大きい電流が前記方向に流れるよう形成された幹線用電極とが、交互に並んだ部分を有することを特徴とするＧａＮ系半導体受光素子。

【請求項７】　ＧａＮ系材料からなる発光層を有するＧａＮ系半導体発光素子であって、発光層に対し光が外界へ出ていく側を上部側として、発光層の上部側には、電極を形成するためのＧａＮ系材料からなるコンタクト層を介して上部電極が設けられ、
該上部電極の形成パターンは、該電極がコンタクト層上面を覆う被覆領域と、該電極がコンタクト層上面を覆わず露出させる露出領域とが交互に並んだ繰り返し部分を有する形成パターンであって、
コンタクト層上面のうち、露出領域には凹部が設けられていることを特徴とするＧａＮ系半導体発光素子。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、ＧａＮ系半導体材料を用いた半導体発光素子、受光素子の技術分野に属する。

【０００２】

【従来の技術】ＧａＮ系発光素子は、ＧａＮ系材料を用いた半導体発光素子であって、近年高輝度の発光ダイオード（ＬＥＤ）が実現されたのを機会に研究が活発に行われており、半導体レーザの室温連続発振の報告も聞かれる様になっている。ＧａＮ系とは、$In_aGa_bAl_cN$（$0 \leq a \leq 1$、$0 \leq b \leq 1$、$0 \leq c \leq 1$、$a+b+c=1$）で表される化合物半導体を意味する。

【０００３】以下、本明細書では、素子の説明のために、結晶基板が下層側に位置しこれにＧａＮ系結晶層が上方へ積み重ねられるものとして、素子の積層構造に上下方向の区別を設け、「上層」「上面」「上方」などの語句を用いる。

【０００４】ＧａＮ系発光素子の一般的な構造は、図８に示すように、結晶基板１０上に、ｐｎ接合による発光

層２２を含むＧａＮ系結晶層の積層体２０を成長させた構造を有する。電極は、積層体２０の最上層の結晶層をオーミック電極を形成するためのコンタクト層として、その上に上部電極Ｐ１０（通常ｐ型）が形成される。また発光層よりも下側にある下部電極は、通常は結晶基板（サファイア結晶基板）が絶縁性であるために、積層体２０の一部を除去して、下側のコンタクト層２１を部分的に露出させ、その面に下部電極Ｐ２０（通常ｎ型）が形成される。

【０００５】発光層から発せられた光を上方に放出させる場合、上部電極の形態パターンとして、図８（ｂ）に示す様な、櫛（くし）形パターンや、図８（ｃ）に示す様な、透光性電極の態様が挙げられる。図８（ｂ）のくし形パターンの電極は、発光面上に部分的に電極を設けた構造の一態様で、電流を拡散し、電極のない開口部から発光した光を取り出す構造になっている。図８（ｃ）の透光性電極は、電極材料を薄膜状に形成して透光性を持たせたものであり、電極直下での発光を透光性電極を通して外に取り出す構造になっている。いずれも、積層体内に流れる電流をより多く、より広げながらも、一方では、上部電極を形成する面からより多くの光を外部へ放出しようとした構成である。

【０００６】一方、ｐｎ接合による光起電力を取り出すタイプのＧａＮ系受光素子の構造においても、受光対象光を入射させる側の電極（上部電極）を、くし形パターンの電極や、透光性電極の態様とする場合がある。これは、いずれも、上部電極を形成する面からより多くの受光対象光を素子内へ広く入射させようとしながらも、一方では、内部のｐｎ接合で発生した光起電力をより効率よく多く集めようとする構成である。

【０００７】

【発明が解決しようとする課題】しかし、従来のＧａＮ系発光素子、ＧａＮ系受光素子では、電極の幅や電極間の間隙に対してなんら数値的な規定がない。例えば、発光素子において、くし形パターンの電極のように部分的に設けられた上部電極の構造では、電流はほぼ電極直下のみにしか流れず、発光層での発光は電極直下のみとなる。従って、くし形パターンの電極の態様であっても、最も強く発光する部分の直上には電極の導体部分が存在し、光を上方に取り出す際には、電極の導体部分での反射・吸収によって取り出し効率が悪いということになる。

【０００８】発光素子において、透光性電極を用いた態様では、透光性を確保するためにその膜厚を最小限に抑える必要がある。しかし膜厚が小さくなると、その電極のシート抵抗が増加するため、電極での電圧降下が大きくなってしまう。またシート抵抗が極端に大きくなると、電流が面の拡張する方向に十分に広がらず、その結果部分的にしか発光しなくなってしまう。また逆に電極膜厚を大きくすると、シート抵抗は小さくなるが、透光

性が低下し、発光した光の外部への取り出し効率が悪くなってしまう。

【０００９】また、受光素子においては、くし形パターンの電極では、露出部（電極間隔）が狭すぎると感度が悪くなり、逆に広すぎるとキャリアの発生を電極に取り出すのに損失を受け、感度が悪くなる。また、透光性電極では、受光対象光をより多く素子内に入れるために膜厚を薄くすると、その電極のシート抵抗が増加し、微量な電流を高密度に集めることができない。逆に電極膜厚を大きくすると、シート抵抗が小さくなるが、透光性が低下し、受光対象光の入射量が減少する。

【００１０】本発明の課題は、ＧａＮ系発光素子において、光を取り出す側の電極の構造を改善し、より発光特性の優れた素子を提供することである。

【００１１】また、本発明の他の課題は、ＧａＮ系受光素子において、光を取り入れる側の電極の構造を改善し、より受光特性の優れた素子を提供することである。

【００１２】

【課題を解決するための手段】本発明のＧａＮ系半導体発光素子およびＧａＮ系半導体受光素子は、以下の特徴を有するものである。

（１）ＧａＮ系材料からなる発光層を有するＧａＮ系半導体発光素子であって、発光層に対し光が外界へ出ていく側を上部側として、発光層の上部側には、電極を形成するためのＧａＮ系材料からなるコンタクト層を介して上部電極が設けられ、該上部電極の形成パターンは、該電極がコンタクト層上面を覆う被覆領域と、該電極がコンタクト層上面を覆わず露出させる露出領域とが交互に並んだ繰り返し部分を有する形成パターンであって、前記繰り返し部分において、繰り返しの方向に関する個々の被覆領域の幅をＷとし個々の露出領域の幅をＧとし、コンタクト層上面から発光層までの深さをｄ、コンタクト層の屈折率をｎ１、外界の屈折率をｎ２とするとき、$W \leq 10\,\mu m$、$W \leq 2G$、$G \leq d \times \tan\theta 1$（ただし、$\theta 1 = \sin^{-1}(n2/n1)$）、であることを特徴とするＧａＮ系半導体発光素子。

【００１３】（２）ＧａＮ系材料のｐｎ接合によって光電流に係るキャリアを発生する光検出層を有するＧａＮ系半導体受光素子であって、光検出層に対し受光対象光が入射する側を上部側として、光検出層の上部側には、電極を形成するためのＧａＮ系材料からなるコンタクト層を介して上部電極が設けられ、該上部電極の形成パターンは、該電極がコンタクト層上面を覆う被覆領域と、該電極がコンタクト層上面を覆わず露出させる露出領域とが交互に並んだ繰り返し部分を有する形成パターンであって、前記繰り返し部分において、繰り返しの方向に関する個々の被覆領域の幅をＷとし個々の露出領域の幅をＧとし、コンタクト層上面から発光層までの深さをｄ、コンタクト層の屈折率をｎ１、外界の屈折率をｎ２とするとき、$W \leq 10\,\mu m$、$W \leq 2G$、$G \leq d \times \tan$

θ１（ただし、θ１＝ｓｉｎ$^{-1}$（ｎ２／ｎ１））、であることを特徴とするＧａＮ系半導体受光素子。

【００１４】（３）ＧａＮ系材料からなる発光層を有するＧａＮ系半導体発光素子であって、発光層に対し光が外界へ出ていく側を上部側として、発光層の上部側には、電極を形成するためのＧａＮ系材料からなるコンタクト層を介して上部電極が設けられ、該上部電極が、発光層からの光を透過し得るように薄膜とされた透光性電極と、該透光性電極よりも大きい電流が電極形成面の方向に通過可能とされた幹線用電極とが、交互に並んだ部分を有することを特徴とするＧａＮ系半導体発光素子。

【００１５】（４）透光性電極がオーミック電極であって、幹線用電極がショットキー電極である上記（３）記載のＧａＮ系半導体発光素子。

【００１６】（５）コンタクト層の内部における、幹線用電極の直下で該電極に接した部位に、または上記幹線用電極の直下で該電極から離れた部位に、電流の妨害となり得る電流阻止層が形成されている上記（３）記載のＧａＮ系半導体発光素子。

【００１７】（６）ＧａＮ系材料のｐｎ接合によって光電流に係るキャリアを発生する光検出層を有するＧａＮ系半導体受光素子であって、光検出層に対し受光対象光が入射する側を上部側として、光検出層の上部側には、電極を形成するためのＧａＮ系材料からなるコンタクト層を介して上部電極が設けられ、該上部電極が、受光対象光を透過し得るように薄膜とされた透光性電極と、該透光性電極よりも大きい電流が電極形成面の方向に通過可能とされた幹線用電極とが、交互に並んだ部分を有することを特徴とするＧａＮ系半導体受光素子。

【００１８】（７）ＧａＮ系材料からなる発光層を有するＧａＮ系半導体発光素子であって、発光層に対し光が外界へ出ていく側を上部側として、発光層の上部側には、電極を形成するためのＧａＮ系材料からなるコンタクト層を介して上部電極が設けられ、該上部電極の形成パターンは、該電極がコンタクト層上面を覆う被覆領域と、該電極がコンタクト層上面を覆わず露出させる露出領域とが交互に並んだ繰り返し部分を有する形成パターンであって、コンタクト層上面のうち、露出領域には凹部が設けられていることを特徴とするＧａＮ系半導体発光素子。

【００１９】ＧａＮ系とは、$In_aGa_bAl_cN$（０≦ａ≦１、０≦ｂ≦１、０≦ｃ≦１、ａ＋ｂ＋ｃ＝１）で示される化合物半導体を意味する。

【００２０】

【作用】上記（１）の発光素子の態様では、上部電極の繰り返し部分（具体的には、くし形パターンの電極の「くしの歯」に相当する部分）において、上記（１）のように、Ｗ、Ｇ、ｄ、ｎ１、ｎ２を、①Ｗ≦１０μｍ、②Ｗ≦２Ｇ、③Ｇ≦ｄ×ｔａｎθ１、と規定している。これら①～③の限定が揃うことによって、発光層から発せられた光を電極での反射・吸収が最小限に抑えられ、光取り出し効率が向上する。これを図２で簡単に説明する。

【００２１】上記①と②との限定は、被覆領域（電極Ｐ１の幅）を数値限定するとともに、被覆領域と露出領域との比の好ましい大小関係を限定したものである。上記①の限定によって、先ず、電流の注入口の大きさの好ましい数値範囲が限定され、これに上記②の限定が加えられて、光の放出口の大きさの好ましい数値範囲および電流の注入口との関係が限定される。上記②において２Ｇ＜Ｗでは、上部ｐクラッド層により外部に光を取り出す領域が小さくなり、つまり、外部取り出し効率が悪くなり、好ましくない。

【００２２】上記①と②の限定によって、外界に出ていく光にとって好ましい開口と障害の関係が確定し、しかもその障害から直下にｄだけ離れた部分では光が発生する。この条件を揃えた上で、上記③の限定が加えられる。これは、図２に示すように、屈折の法則に基づくｄとＧとの好ましい関係である。上部電極下面から直下にｄだけ離れて位置する発光層から発せられた光Ｌ１は、屈折角θ１をもってＧａＮ系結晶層から外界に出ていく。このとき、Ｇ≦ｄ×ｔａｎθ１とすることによって、図２中、ｍ１（電極中心直下）からｍ２（電極端部直下）までの間で発せられた光Ｌ１を、層Ｓ３の上面（Ｇの領域）全域で外部に取り出せる。それより左の上面では全反射され、光が出てこない。

【００２３】上記（２）の受光素子の態様では、Ｗ、Ｇ、ｄ、ｎ１、ｎ２を上記（２）のように、Ｗ、Ｇ、ｄ、ｎ１、ｎ２を、④Ｗ≦１０μｍ、⑤Ｗ≦２Ｇ、⑥Ｇ≦ｄ×ｔａｎθ１（ただし、θ１＝ｓｉｎ$^{-1}$（ｎ２／ｎ１））と規定することによって、光検出層への光の量を充分に確保でき、かつ発生したキャリアを効率よく集めることができ、感度が向上する。

【００２４】上記（３）の発光素子の態様では、透光性電極と、幹線用電極とを、交互に配置することにより、発光層上部における電圧降下を最小限に抑え、幹線用電極を通じて透光性電極全体に電流を行き渡らせることができる。その結果、発光層全域に充分に電流が流れ、全面が発光する。

【００２５】上記（３）の発光素子の態様にさらに加えて、上記（４）、（５）の態様として、幹線用電極とコンタクト層との間で直接的に流れる電流を抑制することで、図６（ａ）、（ｂ）に電流経路を矢印で示すように、電流は、幹線用電極直下には流れず、透光性電極の直下に流れるので、発光した光の透光性電極からの取り出し効率が良くなる。

【００２６】上記（６）の受光素子の態様では、透光性電極と、幹線用電極とを、交互に配置することにより、透光性電極の直下で発生した電流を、透光性電極で受けた後、速やかに幹線用電極に集めることができ、応答速

度、感度が向上する。

【００２７】上記（７）の発光素子の態様では、上部側のコンタクト層上面のうちの露出領域に凹部を設けたことによって、発光層までの層の厚みが薄くなり、発光層から発せられた光がコンタクト層で減衰するのを防止でき、光取り出し効率が高くなる。これによって、例えば、発光層での発光波長を３５０ｎｍのような紫外線とする場合でも、ｐ型コンタクト層にＧａＮを用いることができる。一方、電極下部については、発光層までの層の厚みは充分に厚く確保されているため、電極材が発光層へ拡散することによる寿命の低下が防止できる。

【００２８】

【発明の実施の形態】先ず、上記（１）の発光素子の態様について説明する。図１は、上記（１）の発光素子の構成例を示す図であって、発光層としてダブルヘテロ接合構造（ＤＨ構造）を有するＧａＮ系発光ダイオード（ＬＥＤ）を示している。以下、素子構造を説明する際には、サファイア基板上にＧａＮ系結晶層を成長させた構成例を用い、上部電極をｐ型、下部電極をｎ型として説明するが、これに限定されず、ｐ型、ｎ型の上下が逆の態様や、導電性を有する結晶基板を用いて電極の位置を変更した態様などは、自由に組み合わせてよい。

【００２９】同図の例では、図１（ａ）に示すように、結晶基板１上にバッファ層（図示せず）を介して、ｎ型コンタクト層とｎ型クラッド層とを兼ねるｎ型ＧａＮ層Ｓ１、ＩｎＧａＮ活性層Ｓ２、ｐ型コンタクト層とｐ型クラッド層とを兼ねるｐ型ＧａＮ層Ｓ３が形成されており、この積層体の一角が部分的にエッチングされてｎ型ＧａＮ層Ｓ１が露出した構造となっている。この露出したｎ型ＧａＮ層Ｓ１には、下部電極（ｎ型電極）Ｐ２が形成され、エッチングで残された積層体の最上面には上部電極（ｐ型電極）Ｐ１が形成されている。

【００３０】上部電極Ｐ１の形成パターンは、図１（ｂ）に示すように、くし形パターンの電極となっており、コンタクト層の上面においては、「くしの歯」に相当する部分に覆われた領域が被覆領域であり、「くしの歯」の間隙に相当する部分が露出領域である。被覆領域と露出領域は縞状に交互に並んだ繰り返し部分となっている。上部電極Ｐ１のうち突起した部分Ｐ１ａは、ワイヤーボンディング用に用いられるボンディング用電極である。図１（ｂ）に示す上部電極のＡ－Ａ断面のうち、繰り返し部分を拡大したものが図２である。図２に示すように、電極幅をＷ、電極間の間隙をＧ、コンタクト層の屈折率をｎ１、外界（通常、大気）の屈折率をｎ２、ｐ型コンタクト層上面から発光層までの距離をｄとして、上記作用の説明で述べたように、①～③の限定がなされている。

【００３１】繰り返し部分の電極の形成パターンは、くし形パターンであっても良いし、図３（ａ）に示すような格子状、図３（ｂ）に示すような同心の円弧状、その他、同心円状など、被覆領域と露出領域とが交互に繰り返すパターンであればよい。また、同一周期で繰り返すだけでなく、上記①～③の限定の範囲内ならば、被覆領域と露出領域とが、規則的にまたは不規則に変化して、交互に配置されるパターンであってもよい。

【００３２】上部電極の繰り返し部分の厚みは限定されないが、厚すぎると光の通過の障害となるため、０．０１μｍ～２μｍ程度が好ましい範囲である。また、上部電極に透光性を持たせれば、電極を通して発光を取り出せるので好ましい。

【００３３】電極材料は、電極／半導体層界面での電圧降下を抑制するために、オーミック性の材料がよく、公知の材料を用いてよい。例えば、Ａｕ、Ｎｉ、Ｐｔ、Ｐｄ、Ｉｒ、Ｃｏ、Ｃなどの中から一つ以上の単体あるいは積層構造、合金を用いる態様が挙げられる。

【００３４】発光素子中における、発光のメカニズムに直接関係する構造としては、単純なｐｎ接合による２層（ＨＯＭＯ、ＳＨ）、ＤＨ（ダブルヘテロ接合）による３層の他、超格子構造を有するＳＱＷ（Single Quantum Well）、ＭＱＷ（Multiple Quantum Well）、量子ドットを有する構造などが挙げられる。このなかで、本発明でいう発光層とは、２層のｐｎ接合の場合では接合の界面に生じる空乏層であり、ＤＨでは活性層である。また、ＳＱＷ、ＭＱＷ、量子ドット構造の場合は、バリア層とウエル層とを含んだ井戸型ポテンシャルの構造全体が発光層である。

【００３５】ｐ型コンタクト層上面から発光層までの距離ｄとは、発光層が活性層の場合には、コンタクト層上面から活性層の上面までの距離である。また、発光層が、ＳＱＷ、ＭＱＷ、量子ドット構造の場合も、コンタクト層上面から、井戸型ポテンシャル構造の上面、即ち、バリア層のうちの最上層の上面までの距離である。２層のｐｎ接合の界面に生じる空乏層を発光層とする場合のみ、近似的に、コンタクト層上面からｐｎ接合の界面までの距離をｄとする。

【００３６】コンタクト層は、オーミック電極を形成するために独立して設けられたＧａＮ系結晶層、また、図１のようにクラッド層と兼用する層、ｐｎ接合を構成する一方の層であってよい。いずれの場合であっても、発光層からの光を吸収しないように、該光よりも大きなバンドギャップの材料が用いられる。

【００３７】コンタクト層の屈折率ｎ１は、コンタクト層の材料によっても異なるが、例えば、波長４５０ｎｍの光に対して、ＧａＮでは２．４９３、$Al_{0.1}Ga_{0.9}N$では２．４２６などとなる。外界の屈折率ｎ２は、コンタクト層上面を屈折の界面として、その外側を取り巻く部分（真空または物質）の屈折率である。最も一般的な使用環境である大気中での使用の場合には、空気の屈折率ｎ２＝１となる。

【００３８】コンタクト層の材料にはＧａＮ系材料が用

いられるが、発光層から発せられた光のエネルギーよりも大きなバンドギャップの材料を用い、光を吸収させないようにするのがよい。例えば、紫外線発光の場合は、バンドギャップの大きなＡｌＧａＮが望ましい。ただしＡｌ組成を高くすると発光側電極がオーミック特性を得にくくなる。

【００３９】オーミック電極とは、好ましくは、金属－半導体の接触が整流特性を示さないものであって、例えば、Ｓ．Ｍ．Ｓｚｅ著（南日康夫ら訳）“半導体デバイス”，産業図書（初版第３刷、１６３頁）の記載が参照される。

【００４０】ＧａＮ系結晶を成長させる方法は、ＨＶＰＥ、ＭＯＣＶＤ、ＭＢＥ法などが挙げられ、特に、ＭＯＣＶＤ・ＭＢＥ法が好ましい。

【００４１】上記（２）の受光素子の態様については、素子としての構造は図１と同様である。また、発光層を光検出層とし、外界からの受光対象光がコンタクト層上面の露出領域から素子内に入射するとして、上部電極、ｐ型コンタクト層などの各部の説明は上記（１）の説明を準用する。

【００４２】次に上記（３）の発光素子の態様について説明する。素子全体の積層構造については、上部電極の構造以外は、上記（１）の発光素子と同様であり、図１（ａ）の構造、図８の従来の素子の構造などが参照される。この発光素子の上部電極Ｐ１は、図５（ａ）に示すように、透光性電極Ｐ１１と、幹線用電極Ｐ１２とが交互に互いに導通状態となるよう接触しながら並んだ部分を有する。透光性電極Ｐ１１は、発光層からの光を透過し得るように薄膜とされた電極である。幹線用電極Ｐ１２は、透光性電極Ｐ１１中を、面方向に流れる電流よりも大きい電流が同方向に通過可能とされた電極、即ち、シート抵抗のより小さい電流供給用の電極である。面方向とは、電極形成面（コンタクト層の上面）が拡張する方向である。また、図５（ａ）に示す、ＧａＮ系結晶層の積層構造は、ｎ型クラッド層Ｓ１、活性層Ｓ２、ｐ型クラッド層（＝コンタクト層）Ｓ３である。

【００４３】透光性電極の材料は、電極／半導体層界面での電圧降下を抑制するために、オーミック性の材料がよく、上記（１）の発光素子で示した材料を用いることができる。透光性電極の厚さは、透光性を確保するために、０．００５μｍ～０．０５μｍが好ましい。

【００４４】幹線用電極は、材料自体は透光性電極と同じものを用いてよいが、透光性電極を流れる電流よりも大きい電流が通過可能なように、即ち、透光性電極よりもシート抵抗が低いように形成する。具体的には、より厚く形成する態様が挙げられ、その場合には、充分な電流量を確保するために、０．０１μｍ～２μｍが好ましい。

【００４５】幹線用電極と透光性電極との形成パターン、即ち、コンタクト層上面における互いの組み合わせパターンは限定されない。図５（ｂ）に示す例では、コンタクト層上面を、幹線用電極Ｐ１２によって大きく３つの正方形の区画に分割し、各正方形の区画に透光性電極Ｐ１１を設けている。その他、幹線用電極のパターンを、図１（ｂ）のくし型、図３（ａ）の格子状、図３（ｂ）の同心の円弧状、同心の円状、放射状などのパターンとし、各々の幹線用電極の間隙に透光性電極を設けたパターンとしてもよい。特に、図４（ａ）や図４（ｂ）に示すように、ｎ電極Ｐ２に対して距離が同じになるように各々の幹線用電極を配置すると、発光が均一になってよい。また、上記（１）の発光素子の上部電極の限定条件のうちＷ≦１０μｍ、Ｗ≦２Ｇ、を適用してもよい。

【００４６】上記作用の説明で述べたように、この（３）の発光素子では、幹線用電極とコンタクト層との間で直接的に流れる電流を抑制し、透光性電極の下方に電流を流す態様が挙げられる。具体的に、電流を抑制するには、幹線用電極をショットキー性のものとする態様、図６（ｂ）に示すように、コンタクト層Ｓ３の内部において、幹線用電極の直下に、電流の妨害となり得る電流阻止層Ｑを設ける態様が挙げられる。電流阻止層Ｑは、電極に接して（即ち、コンタクト層上面に露出させて）設けてもよく、また、幹線用電極の直下で該電極から離れた部位に設けてもよい。

【００４７】幹線用電極をショットキー性として形成するには、ｐ型層の場合、Ａｌ、Ｔｉ、Ｔａ、Ｓｉなどの中から単体、または複数の材料を選択して用いればよい。ショットキー性電極の形成方法は限定されないが、透光性電極を形成し、これに電極アニールにてオーミック性を持たせた後、幹線用電極をショットキー電極として形成する手順が好ましい。

【００４８】電流阻止層は、上記のように、コンタクト層上面に露出した状態とするか、コンタクト層内に埋設された状態として、部分的に設ける。電流阻止の作用を得るためには、周囲と異なる導電型（ｐ型コンタクト層の場合はｎ型）とする態様、アンドープなどによって高抵抗なＧａＮ系結晶層とする態様、絶縁材料（例えばSiO_2、Si_3N_4、Al_2O_3など）を用いる態様などが挙げられる。

【００４９】上記（６）の受光素子の態様については、素子としての積層構造は図１と同様である。上部電極の構造については、上記（３）の発光素子の説明を準用する。ただし、受光素子であるために、上記（３）の発光素子とは異なり、幹線用電極をショットキー性にする態様、幹線用電極の直下に電流阻止層を設ける態様などは不要である。また、上記（２）の受光素子、上記（６）の受光素子ともに、素子構造は、ｐｉｎ構造タイプでもｐｎ接合タイプでも良い。発明の意図を満たすならば別構造であっても良い。

【００５０】次に、上記（７）の発光素子の態様につい

て説明する。素子全体の積層構造については、上部電極、コンタクト層の構造以外は、上記（１）、（３）の発光素子と同様であり、これらの説明を準用する。図１（ａ）の構造、図８の従来の素子の構造などが参照される。この発光素子には、上部電極だけでなくコンタクト層にも構造上の特徴がある。即ち、上部電極の形成パターンは、上記（１）の発光素子の場合と同様、被覆領域と露出領域とが交互に並んだ繰り返し部分を有する形成パターンであって、図７に示すように、ｐ型コンタクト層（＝ｐ型クラッド層）Ｓ３の上面Ｓ３１（一点鎖線で示している）には、露出領域に凹部Ｓ３２が設けられていることを特徴とする。

【００５１】上部電極は、オーミック電極であればよく、厚さにも規定はないが、光が透過する程度の厚さにすると上部電極の直下からの発光も取り出し可能となるため好ましい。上部電極の形成パターンは、図１（ｂ）のくし型、図３（ａ）の格子状、図３（ｂ）の同心の円弧状、同心の円状、放射状などのパターンが挙げられる。

【００５２】図７に示すｐ型コンタクト層の厚さ、即ち、凹部ではない部分の厚さは、限定されないが、電極材が発光層に拡散することによる素子寿命低下を起こさない程度に厚くするのがよい。一方、コンタクト層が厚すぎると、溝形成に時間がかかるなどの問題があるため、０．１μｍ～５μｍ程度の範囲がよい。

【００５３】凹部は、ｐ型コンタクト層Ｓ３の上面Ｓ３１のうち、露出領域に設けられるが、この領域をより大きく占有するように設けるのが好ましい。従って、凹部の形態は、露出領域の形状に従って、溝が縞状に並んだ状態や、単発的な穴が分散した状態などとなる。

【００５４】凹部の底面から発光層の上面までの厚さは、発光部からの光の取り出し量を多くするためには薄い程良い。即ち、凹部は、活性層上面に達するほど深く形成してもよい。しかし、凹部の形成工程を考慮すると、凹部が深すぎると形成時の歩留まりが悪くなる。

【００５５】上部電極をクシ形のパターンとする場合、繰り返し部分の寸法は、発光素子の規模などにもよるが、「くしの歯」に相当する部分の電極の幅を０．１μｍ～１０μｍ程度とし、導体間の隙間の幅を０．１μｍ～１０μｍとするのが好ましい。

【００５６】凹部形成法はどの様な方法でも良いが、エッチング時の制御性を考えるとリアクティブイオンエッチング（ＲＩＥ）法が一番に挙げられる。このＲＩＥを行う際、凹部以外をエッチングしないようマスクを用いるが、発光側電極そのものをマスクとして用いると工程が簡略化でき非常によい。更にマスク材として用いている電極の厚みがエッチング終了時に透明となる程度に制御すると良い。

【００５７】

【実施例】実施例１

本実施例では、上記（１）の発光素子として図１に示す構造のものを実際に製作した。

〔結晶基板、およびバッファ層〕結晶基板としてはサファイアＣ面結晶基板を用いた。まずこの基板をＭＯＣＶＤ装置内に配置し、水素雰囲気下で１１００℃まで昇温し、サーマルエッチングを行った。その後窒素雰囲気に切り替え、温度を５００℃まで下げ原料としてトリメチルガリウム（以下ＴＭＧ）を、Ｎ原料としてアンモニアを流し、ＧａＮ低温バッファ層を成長させた。

【００５８】〔ＤＨ構造〕温度を１０００℃に昇温し、原料としてＴＭＧ・アンモニアを、ドーパントとしてシランを流し、図１（ａ）におけるｎ型コンタクト層（ｎ型クラッド層）であるｎ型ＧａＮ層Ｓ１を３μｍ成長させた。続いて、トリメチルインジウム（ＴＭＩ）、ＴＭＧ、アンモニア、シランを流し、$In_{0.2}Ga_{0.8}N$活性層Ｓ２を形成した。さらに、ＴＭＧ・アンモニア・ビスシクロペンタジエニルマグネシウム（Ｃｐ２Ｍｇ）を流し、ｐ型コンタクト層（ｐ型クラッド層）であるｐ型ＧａＮ層Ｓ３を５．０μｍ（＝ｄ）成長させた。その後雰囲気ガスを窒素に切り換え室温まで徐冷しサンプルを作製した。

【００５９】成長後、ｐ型コンタクト層Ｓ３の上面に、スパッタにより厚さ２０００Å のSiO_2膜を形成し、その上にフォトリソグラフィによりフォトレジストをパターニング形成し、ドライエッチングにより部分的にｎ型コンタクト層Ｓ１が露出するまで５．５μｍエッチングし、図１（ａ）に示すような積層構造体とした。

【００６０】〔電極の形成〕ｐ型コンタクト層上面のSiO_2膜に対して、フォトリソグラフィ技術によりくし型のパターンを形成し、電子ビーム蒸着により、厚さ５００ÅのＮｉ層、その上に厚さ１０００ÅのＡｕ層を形成した。そしてリフトオフにより、くし型パターンの電極Ｐ１とした。この時の「くしの歯」の部分の電極幅（被覆領域の幅Ｗ）は２μｍ、電極間の間隔（露出領域の幅Ｇ）は２μｍであった。同様にして、ｎ型電極Ｐ２として、厚さ２００ÅのＴｉ層、その上に厚さ２３００ÅのＡｌ層を形成した。更に各電極のオーミック性を得るため６００℃×１０ｍｉｎ電極アニールした。

【００６１】上部電極Ｐ１のうちのボンディング電極Ｐ１ａは、上記と同様にして、厚さ５００ÅのＮｉ層、その上に厚さ１５００ÅのＡｕ層を形成し、リフトオフにより形成した。この試料を、チップに分断し、上記（１）の発光素子として、ＧａＮ系ＬＥＤを得た。

【００６２】得られた発光素子は、Ｗ＝２μｍ、Ｇ＝２μｍ、ｄ＝５．０μｍであって、Ｗ≦１０μｍ、Ｗ≦２Ｇ、Ｇ≦ｄ×$\tan\theta 1$（ただし、$\theta 1=\sin^{-1}(1/2.493)$）を満足している。このＬＥＤをＴｏ－１８ステム台にマウントし、出力を測定したところ、波長４５０ｎｍ、２０ｍＡで、２．５ｍＷであり、図８に示すような従来の発光素子に比べて、同じ電流、電圧

で、高い発光出力が得られた。
【００６３】実施例２
本実施例では、くし形パターンの「くしの歯」の部分の電極幅（被覆領域の幅Ｗ）を１μｍ、電極間の間隔（露出領域の幅Ｇ）を１μｍとしたこと以外は、実施例１と同様の発光素子を形成した。得られた発光素子は、Ｗ＝１μｍ、Ｇ＝１μｍ、ｄ＝５．０μｍであって、Ｗ≦１０μｍ、Ｗ≦２Ｇ、Ｇ≦ｄ×ｔａｎθ１（ただし、θ１＝ｓｉｎ$^{-1}$（１／２．４９３））を満足している。
【００６４】このＬＥＤを、Ｔｏ－１８ステム台にマウントし、出力を測定したところ、波長４５０ｎｍ、２０ｍＡで、３．０ｍＷであり、実施例１の発光素子に比べて発光強度が同等であることがわかった。
【００６５】実施例３
本実施例では、上記（３）の発光素子として図１（ａ）に示す積層構造、図５に示す上部電極構造のものを実際に製作した。結晶基板、バッファ層、ＧａＮ系結晶層Ｓ１、Ｓ２、Ｓ３の積層までは、実施例１と同様である
【００６６】〔透光性電極〕ｐ型コンタクト層（＝ｐ型クラッド層）Ｓ３上に透光性電極を作製した。先ず、フォトリソグラフィ技術により後工程で形成する幹線用電極のためのパターンを形成し、電子ビーム蒸着により、厚さ２５ÅのＮｉ層、その上に厚さ２５ÅのＡｕ層を形成した。そしてリフトオフにより幹線用電極のパターンが抜けた透光性電極を形成した。幹線用電極のパターンは、図５（ｂ）に示す通りである。同様にして、ｎ型電極Ｐ２として、厚さ２００ÅのＴｉ層、その上に厚さ２３００ÅのＡｌ層を形成した。更に各電極のオーミック性を得るため６００℃×１０ｍｉｎ電極アニールした。
【００６７】幹線用電極は、フォトリソグラフィー技術によりパターニングし、電子ビーム蒸着により厚さ２００ÅのＴｉ層、その上に厚さ２３００ÅのＡｌ層を積層し、リフトオフにより形成した。幹線用電極の幅は、前記透光性電極に設けた溝の幅よりも大きく、図６（ｂ）に示すように、幹線用電極の側部が透光性電極の上面に乗り上げて一部が重なり、互いに充分に導通するようにした。
【００６８】上部電極Ｐ１のうちのボンディング電極Ｐ１ａは、実施例１と同様にして、厚さ５００ÅのＮｉ層、その上に厚さ１５００ÅのＡｕ層を形成し、リフトオフにより形成した。この試料をチップに分断し、上記（３）の発光素子として、ＧａＮ系ＬＥＤを得た。
【００６９】このＬＥＤを、Ｔｏ－１８ステム台にマウントし、出力を測定したところ、波長４５０ｎｍ、２０ｍＡで、３．０ｍＷであり、幹線用電極のない従来の透明電極だけのＬＥＤに比べ、順方向電圧が低下し、面内均一な発光が得られ、発光出力が向上した。
【００７０】実施例４
本実施例では、幹線用電極直下のｐ型コンタクト層の表面に、電流阻止層としてSiO_2層を形成したこと以外は、実施例３と同様に発光素子を形成した。SiO_2層は、透光性電極を形成する前にフォトリソグラフィ技術、スパッタ、リフトオフにより、SiO_2層の上面とｐ型コンタクト層の上面とが同一になるように形成した。
【００７１】チップに分断し、上記（３）の発光素子のバリエーションとしてのＧａＮ系ＬＥＤを得た。このＬＥＤを、Ｔｏ－１８ステム台にマウントし、出力を測定したところ、波長４５０ｎｍ、２０ｍＡで、３．０ｍＷであり、実施例３のＬＥＤに比べ、同等の発光強度が得られた。
【００７２】実施例５
本実施例では、上記（７）の発光素子として、図１（ａ）に示す積層構造、図７に示す、上部電極構造およびｐ型コンタクト層構造を有するＧａＮ系ＬＥＤを実際に製作した。結晶基板、バッファ層、ＧａＮ系結晶層Ｓ１、Ｓ２、Ｓ３の積層までは、実施例１と同様の工程である。ただし、ｐ型ＧａＮコンタクト層Ｓ３の層厚を０．５μｍとした。
【００７３】得られたサンプルをドライエッチングによりｐ型ＧａＮコンタクト層Ｓ３と活性層Ｓ２の一部をエッチング除去し、ｎ型コンタクト層Ｓ１を露出させ、ｎ型電極Ｐ２を形成した。
【００７４】次に、図７に示すように、ｐ型コンタクト層Ｓ３の上面Ｓ３１に、凹部Ｓ３２を形成するためSiO_2膜でマスクパターンを形成した。このマスクパターンは、上部電極を形成する面をくし型パターンに残すマスクパターンであって、くし形部分の寸法仕様は、電極幅２μｍ、溝状の凹部幅４μｍとした。その後ドライエッチングにより、上面Ｓ３１から凹部を掘り下げ、活性層上面の近傍まで達する凹部を形成した。
【００７５】次に、残された上面Ｓ３１に、実施例１と同様にして上部電極をくし型パターンとして形成した。この試料をチップに分断し、上記（３）の発光素子として、ＧａＮ系ＬＥＤを得た。このＬＥＤを、Ｔｏ－１８ステム台にマウントし、出力を測定したところ、波長４５０ｎｍ、２０ｍＡで、２．５ｍＷであり、凹部のない従来のくし形パターンの電極のＬＥＤに比べ、光取り出し効率が向上することがわかった。
【００７６】実施例６
本実施例では、ｐ型コンタクト層上面に、凹部形成よりも先にくし形パターンの電極を形成しておき、凹部形成に用いるマスクをＡｕ／Ｎｉ電極自体としたこと以外は、実施例５と同様に発光素子を形成した。その結果、実施例５と同一の構造が工程を簡略して作製できることがわかった。
【００７７】
【発明の効果】上記説明のように、本発明による上部電極構造の種々の改善によって、より発光特性の優れたＧａＮ系発光素子、および、より受光特性の優れたＧａＮ

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系受光素子が得られるようになった。

【図面の簡単な説明】

【図１】本発明による発光素子ＧａＮ系発光素子の構造の一例を示す図である。また、本発明の受光素子の構造の一例としても参照することができる。

【図２】図１（ｂ）に示す上部電極のＡ－Ａ断面のうち、繰り返し部分を拡大して示す図である。

【図３】本発明による発光素子の、上部電極の繰り返し部分の形成パターンを例示する図である。また、本発明による受光素子の、上部電極の繰り返し部分の形成パターンの例としても参照することができる。

【図４】本発明による発光素子の、上部電極の繰り返し部分の形成パターンの他の例を示す図である。また、本発明による受光素子の、上部電極の繰り返し部分の形成パターンの例としても参照することができる。

【図５】本発明による発光素子の、上部電極の形成パターンを例示する図である。また、本発明による受光素子の、上部電極の形成パターンの例としても参照することができる。

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【図６】本発明による発光素子の、上部電極の他の態様を例示する図である。

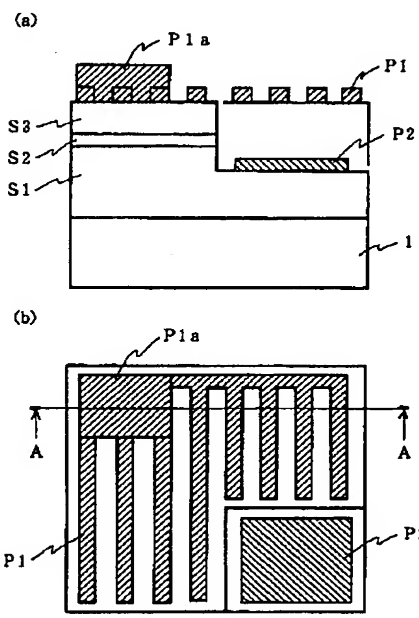
【図７】本発明による発光素子の、上部電極およびｐ型コンタクト層の構造の一例を示す図である。

【図８】従来のＧａＮ系発光素子の積層構造、電極のパターンを示す図である。

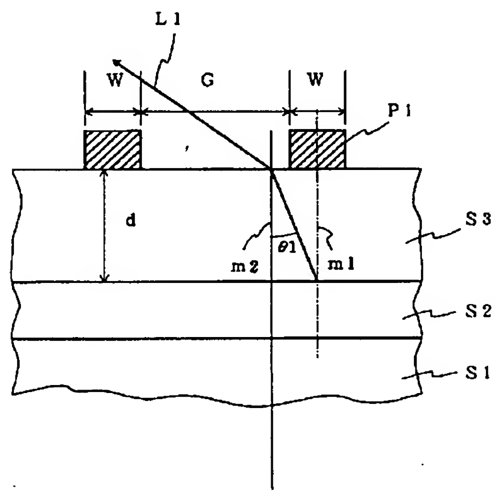
【符号の説明】

Ｓ１　ｎ型コンタクト層（クラッド層）
Ｓ２　発光層（活性層）
Ｓ３　ｐ型コンタクト層（クラッド層）
Ｌ１　光
Ｐ１　上部電極

【図１】

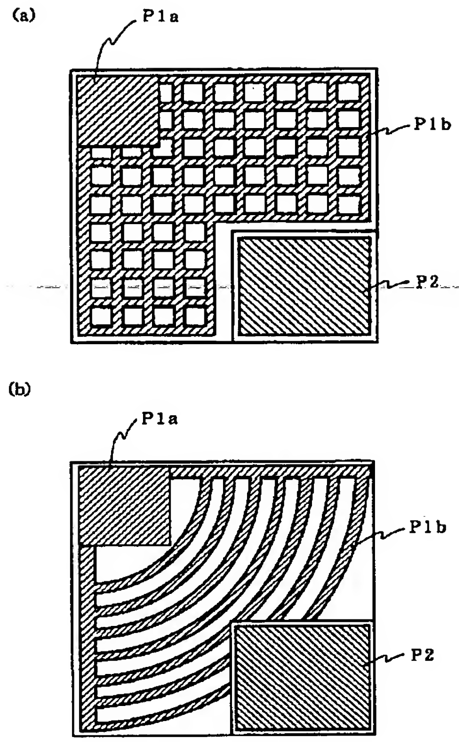


【図２】

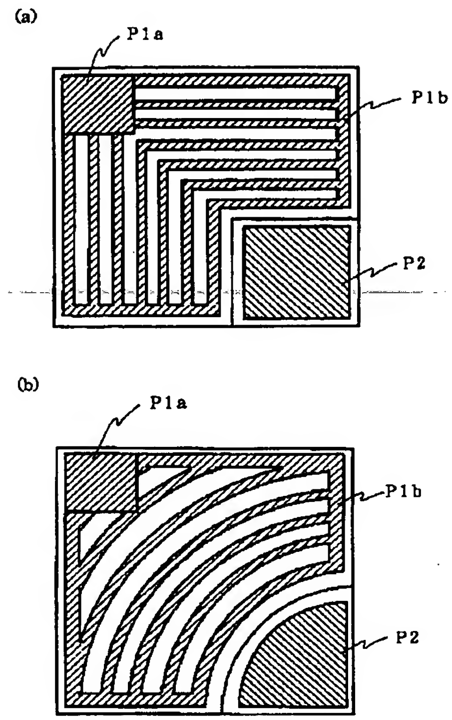


Ｓ１　ｎ型コンタクト層（クラッド層）
Ｓ２　発光層（活性層）
Ｓ３　ｐ型コンタクト層（クラッド層）
Ｌ１　光
Ｐ１　上部電極

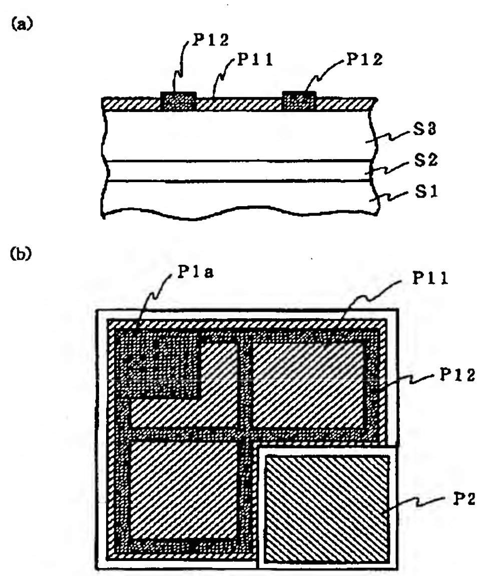
【図３】


(a)
P1a
P1b
P2
(b)
P1a
P1b
P2

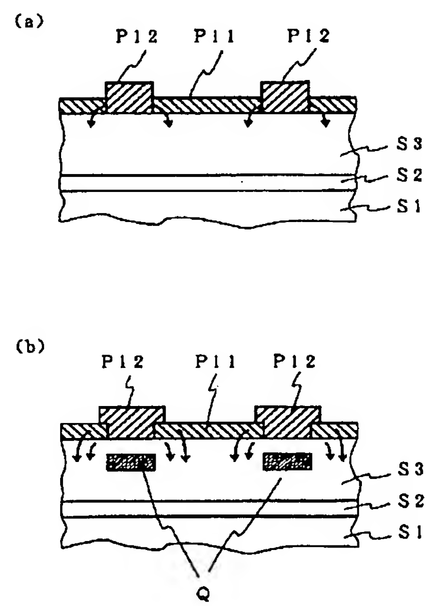
【図４】


(a)
P1a
P1b
P2
(b)
P1a
P1b
P2

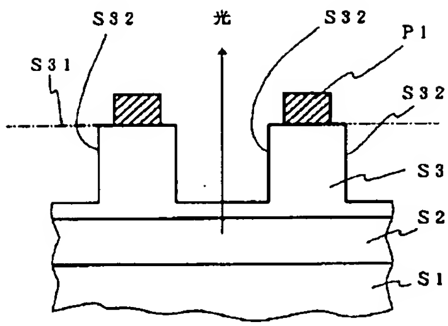
【図５】


(a)
P12
P11
P12
S3
S2
S1
(b)
P1a
P11
P12
P2

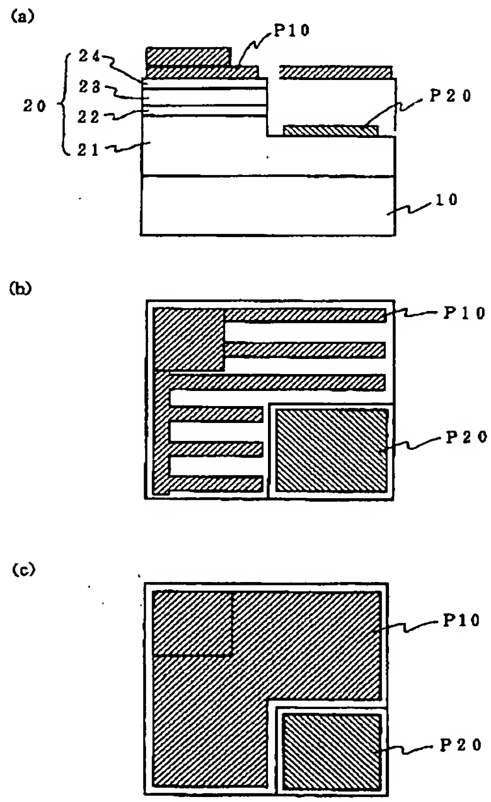
【図６】


(a)
P12
P11
P12
S3
S2
S1
(b)
P12
P11
P12
S3
S2
S1
Q

【図７】



【図８】



フロントページの続き

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